FILE COPY

CHATHAM (STAGE) HARBOR

MASSACHUSETTS

DESIGN MEMORANDUM

MAINTENANCE OF CHANNEL

CONSTRUCTION OF DIKE

U.S. ARMY ENGINEER DIVISION, NEW ENGLAND
CORPS OF ENGINEERS
WALTHAM, MASS.

27 JULY 1962

U. S. ARMY ENGINEER DIVISION, NEW ENGLAND
CORPS OF ENGINEERS
424 TRAPELO ROAD
WALTHAM 54, MASS.

ADDRESS REPLY TO:
DIVISION ENGINEER

REFER TO FILE NO.

FILE COPY

NEDGW

27 July 1962

SUBJECT: Design Memorandum on Chatham (Stage) Harbor, Mass.

TO: Chief of Engineers
ATTN: ENGCW-OM
Department of the Army
Washington 25, D. C.

1. Reference is made to Chief of Engineers letter ENGCW-OM, Subject: "Operation and Maintenance Program, FY 1962" dated 7 December 1961 in reply to New England Division letters NEDVN, Subject: "Justification of Additional O&M Funds, FY 1962" dated 22 November 1961, and NEDVN, Subject: "Chatham (Stage) Harbor, Massachusetts", dated 14 November 1961.

2. The existing project at Stage Harbor providing for an entrance channel 10 feet deep was authorized in 1945 and completed in 1957 at a cost of $302,500. Excessive shoaling has occurred as a result of a breach in adjacent Monomoy Beach. The local commercial fishing fleet and larger recreational craft can now enter the harbor only because the Town of Chatham had a new minimum channel dredged in June 1962 to permit navigation this summer. The inclosed design memorandum details the results of studies to select the best method of maintaining the Federal project. A plan to relocate the channel slightly and construct a dike to close the breach in Monomoy Beach at a cost of $650,000 is recommended. Ten copies of the Design Memorandum are inclosed in accordance with EM 1110-2-1150 for review. Approval of emergency maintenance by the proposed plan is requested.

3. Funds allocated to the project have been $302,500 for the work completed in 1957 (including $43,500 contributed by local interests), and $12,500 allocated in FY 1962 for study of the excessive shoaling problem. The amount of $650,000 will be required for completion of the recommended plan. Of this amount, $12,000 will be required for completion of preconstruction planning.

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4. It is proposed to request funds for completion of this maintenance work in FY 1964. In view of the urgency of the problem and the probability that the cost will increase each year that construction is delayed it is planned to use funds now available to prepare plans and specifications and advertise for bids in FY 1963 with a view to starting construction as early in July 1963 as possible. The estimate of fund requirements is based on this proposed schedule of work.

1 Incl (10 cys)
Design Memorandum

SEYMOUR A. POTTER, JR.
Brigadier General, USA
Division Engineer

U. S. ARMY ENGINEER DIVISION, NEW ENGLAND
CORPS OF ENGINEERS
424 Trapelo Road
Waltham 54, Mass.

NEDGW

27 July 1962

DESIGN MEMORANDUM ON CHATHAM (STAGE) HARBOR, MASS.

(MAINTENANCE OF CHANNEL

- CONSTRUCTION OF SAND DIKE)

PERTINENT DATA

Project Authorization: 1945.

Project Document: House Document No. 456, 77th Congress, 1st Session.

Date of Survey Report: 26 April 1941.

Date of Completion of the Authorized Project: 1957.

The Present Problem: Recent breaching of Monomoy Beach south of Morris Island has resulted in excessive and continual shoaling of the Federal channel into Stage Harbor.

Proposed Solution: Redredge the channel in a slightly different location and construct a dike to close the breach in Monomoy Beach.

First Cost of Project:		
	Completed Construction	$302,500
	Completed Study of Shoaling Problem	12,500
	Required for Maintenance	650,000
	Total	$965,000

Annual Charges: $47,700.

Primary Annual Benefits: $160,000.

Benefit/Cost Ratio: 3.4 to 1.

Schedule for Accomplishment: Complete planning in FY 1963, start and complete contract work early in FY 1964.

Design Features: Channel 10 feet deep at M.L.W. and 150 feet wide, except at bends. Dike sloping from Elevation +15 above M.L.W. with slope 1 on 20 to east and 1 on 15 to west. Dike about one mile in length to include sand fences and seeding of beach grass.

Design Factors:

Waves: (from the Nantucket Sound) reduced to nearly 2 feet from about 10 feet in deep water.

Tides: mean range about 4.0 feet and spring range 4.7 feet in Stage Harbor. Ocean ranges are 6.6 and 8.1 feet.

Currents: Vary about 1.0 fps at the inlet to Stage Harbor. About 5 fps between Morris Island and Nauset Beach.

Materials: Generally medium to fine sand.

DESIGN MEMORANDUM ON CHATHAM (STAGE) HARBOR, MASS.

(MAINTENANCE OF CHANNEL

- CONSTRUCTION OF SAND DIKE)

PROJECT AUTHORIZATION

1. The present Federal navigation project at Chatham (Stage) Harbor was adopted in 1945 and is described in House Document No. 456, 77th Congress, 1st Session. The project provides for a channel, 10 feet deep and 150 feet wide, from Chatham Roads into Stage Harbor. The project was completed in October 1957 at a Federal cost of $258,816 and no maintenance has been performed on it to date.

2. The requirements of local cooperation specified in the project document are as follows:

> "The project should be subject to the conditions that local interests contribute 50 percent of the cost of new work, but not to exceed $43,500. In addition, local interests should be required to furnish free of cost to the United States suitable disposal areas for new work and subsequent maintenance, if required, and hold and save the United States free from claims resulting from the improvement."

Local interests had made the required cash contribution and complied with the other conditions of local cooperation at the time of project construction.

3. The previous project, adopted in 1890, provided for a channel 6 feet deep and 200 feet wide in the approach portion, 150 feet wide in the portion paralleling Harding Beach on the Chatham Roads side and 100 feet wide in the portion inside the harbor. That project had been completed in 1901 and was last maintained in 1956.

INVESTIGATIONS

4. Project Document. - Investigations made in connection with the survey report of 26 April 1941 printed in House Document No. 456, 77th Congress, 1st Session, included a hydrographic survey of the harbor, the entrance channel, and the offshore area southwest of Harding Beach, determination of the nature of bottom materials in the same locations, and topography of the adjacent shore.

5. Prior to Project Document. - The only prior navigation report was a preliminary examination, dated 27 October 1888, which was followed by a hydrographic survey in 1890, and was the basis of the previous project. No modifications of the previous project had been recommended to Congress. Hydrographic surveys in connection with maintenance of the previous project had been made, as and when required, up until 1956.

6. Concurrent to Project Document. - The Shore Protection Board prepared a report in 1941 on the probable effect of improvement of Stage Harbor on adjacent shore lines, in which it considered the six proposed modifications contained in the survey report of the project document. A pertinent report entitled "Geology of the Coast Line Between Point Gammon and Monomoy Point, Cape Cod, Mass." was prepared in 1939 by the Massachusetts Department of Public Works and the U. S. Department of the Interior, Geological Survey. This report presented pertinent geological information on the project area.

7. Another pertinent report was prepared in 1941 by the Beach Erosion Board in cooperation with the Commonwealth of Massachusetts on a cooperative beach erosion control study of the southerly shore of Cape Cod, Massachusetts (Chatham to Point Gammon). Investigations made in connection with this study which are pertinent to the project area include compilation and analyses of shoreline and offshore changes, study of littoral drift and the movement of sand bars and dunes, compilation and analyses of meteorological and tidal data, topographic and hydrographic surveys, limited observations of tides and waves, current measurements at the mouth of the harbor, sand samples and selected profiles, probings of the bottom at and near the inlet, aerial photographs and inspections of the area.

8. Subsequent to Project Document. - Hydrographic surveys subsequent to the project document have included surveys in connection with the previous project, which was last maintained in 1956, and surveys in connection with the present project, which was constructed in 1957. The surveys since 1950 have been on the following dates:

a. 27 April - 2 May 1950. - Examination of channel outside from the tip of Harding Beach and of the inner harbor area north of Morris Island and of the previous breach in that area.

b. 14-18 March 1953. - Examination of the entire 6' channel.

c. 24-29 February 1956. - Examination and predredging survey of channel along outside shore and around the tip of Harding Beach.

d. 12 June 1956. - Examination after-dredging in vicinity of first bend and around the tip of Harding Beach.

e. 26 July 1956. - Examination after-dredging similar to 12 June 1956.

f. 31 January - 14 February 1957. - Specification survey for present project covering the entire channel.

g. 25 September - 11 October 1957. - After-dredging survey covering the entire channel of the completed present project.

h. 18 - 27 July 1961. - Condition survey of entire channel and of the present breach area, inclusive of adjacent shore.

i. February 1962. - Survey made by the Town of Chatham of and in the vicinity of the tip of Harding Beach in connection with limited dredging undertaken in that area at local expense.

j. 4 - 18 May 1962. - Survey of the shoaled channel around the tip of Harding Beach, of the breach area, of the mouth of Oyster Pond River, where current measurements were made, and profiles across Harding Beach in the vicinity of possible channel relocation. In addition, surface sand samples at selected locations on Harding Beach, the Oyster Pond River, the easterly shore of Morris Island and in the breach area.

k. 10 - 20 July 1962. - Plane table survey of the northerly portion of Monomoy Beach to the south of the present breach.

9. The above 1962 surveys have been made in connection with preparation of the present design memorandum. Additional investigations made for this design memorandum include studies of winds, waves, tides, currents, shore processes and shoaling characteristics, analysis of materials, compilation and analysis of shore front residential property valuations, commercial harbor facilities, fishing commerce and landings, and pleasure boating.

10. A pertinent report, dated 27 July 1956, was prepared by the Corps of Engineers in cooperation with the Commonwealth of Massachusetts on a beach erosion control study of Chatham, Mass. Investigations undertaken in connection with this study included hydrographic surveys of the inner harbor area north of Morris Island and of the previous breach at that location in 1955 and again in 1956, profiles along and across Nauset Beach and across Monomoy Beach taken in March - April 1955, sand samples along selected profiles and at the inner harbor area, tidal observations and analyses, compilation and analysis of shoreline and off-shore changes,

compilation and analyses of wind and wave hindcast data, shore processes studies, and analysis of vessel traffic counts supplied by the U. S. Coast Guard. In addition, the above study incorporated the results of a 1952 report prepared by A. T. Ippen and D. R. F. Harleman for the town, which considered a plan to maintain a navigable opening at the previous breach, current measurements in 1953 at the breach made by the U. S. G. S. and hydrographic surveys of the inner harbor made by the Massachusetts Department of Public Works in 1953 and in 1954. Aerial photographs taken in 1938, 1939, 1952, 1953, 1955 and 1956 were also used in the above study.

11. A pertinent public hearing had been held on 12 March 1954 in Chatham to consider an application by the Massachusetts Department of Public Works for a permit to construct an earth dike across the previous breach thereby rejoining Morris Island to the mainland. As a result of this hearing the above application for permit was withdrawn and the cooperative beach erosion control study of 1956 was initiated. As a result of the findings and recommendations of that study, the Massachusetts Department of Public Works proceeded in 1957 to close the previous breach with a dike.

LOCAL COOPERATION REQUIRED AND VIEWS OF LOCAL INTERESTS

12. Local cooperation required by the authorizing legislation is set forth in Paragraph 2 of this memorandum. Local interests had complied with all requirements at the time of completion of the present project. No additional local cooperation is required for the proposed plan for project maintenance at the present time.

13. The proposed plan and other plans considered were discussed on 19 June 1962 at a conference in Chatham with a selected group of interested persons, and later, on 12 July 1962, they were presented at a public hearing held by the Town in Chatham. The outcome of the hearing was overwhelming support for the proposed plan. Confirming the above, the Board of Selectmen of Chatham formally endorsed the proposed plan by letter dated 16 July 1962, and urged that the utmost be done to have this maintenance approved as an emergency measure, so that it may be completed prior to 1 May 1963, because of its effect on the economy of Chatham.

14. The views of the U. S. Coast Guard, as expressed by the Commander of the local station, were in favor of closure of the breach but preferred a channel relocation across Harding Beach.

15. The views of the U. S. Fish and Wildlife Service, who have jurisdiction of the Fish and Wildlife Refuge on Monomoy Island, as contained in a review draft of their preliminary report, dated 25 June 1962, are in support of the proposed closure of the breach. They express concern, however, that additional breaches across weak points of Monomoy Beach may occur in the future.

16. The Commonwealth of Massachusetts has not presented any official views on the proposed project.

LOCATION OF PROJECT AND TRIBUTARY AREA

17. Chatham (Stage) Harbor is located in the town of Chatham, Massachusetts and is the most easterly harbor on the south shore of Cape Cod. It is a well protected arm of Nantucket Sound; practically landlocked. Stage Harbor contains a mean water area of about 530 acres, of which 300 acres are in the harbor proper, 170 acres are in the Oyster Pond and River tributary to the west and 60 acres are in the Mitchell River and Mill Pond tributary to the north. Stage Harbor is bordered on the east by Morris Island and the dike connecting it to the mainland, on the north and northeast by the mainland of Chatham, and on the west and southwest by Harding Beach. The only present entrance is from Nantucket Sound through the deep water of Chatham Roads. The recently formed breach, south of Morris Island, provides additional direct access to Pleasant Bay and the Atlantic Ocean. (See Plate 1 and oblique aerial photos taken 18 April 1962 and USC & GS vertical negative print taken 23 March 1962).

18. The town of Chatham is about 75 miles southeast of Boston and 80 miles east of Providence, Rhode Island. It is bordered on the north by Pleasant Bay and Orleans, on the west by Harwich, and on the south by Chatham Roads and Nantucket Sound. Monomoy Beach, a recurved spit, about 9 miles in length, which extends south of Morris Island to Monomoy Island, separates Chatham Roads from the Atlantic Ocean.

19. The tributary area is principally developed as a summer resort. More than 1/3 of all dwellings have been estimated to be used seasonally. The major industries, therefore, are the service of the summer population and fishing.

PROJECT PLAN

20. The existing project was authorized in 1945 and constructed in 1957. At the time of authorization Monomoy Beach was connected to Morris Island. In 1956 the beach south of Morris Island was breached by the sea. Since then the beach has widened, deepened and become a continuous waterway. By 1961 sediment moved by tidal currents through the breach extended over a wide area and filled the Stage Harbor channel off the tip of Harding Beach. The shoal front has continued to advance west along the south side of Harding Beach toward the approach channel. Major maintenance is required to restore the project to usefulness.

21. It is estimated that about 310,000 cubic yards of material would have to be removed to restore authorized project dimensions. This would cost about $350,000. However it appears that future maintenance thereafter would be high, about $50,000 annually. A study of the most practicable manner of preserving this harbor indicates that a substantial reduction is possible. The design studies of measures to reduce maintenance costs and alternatives considered are detailed in the Appendix. The plan selected as most desirable is discussed below.

22. The selected plan for project maintenance consists of a channel, 10 feet deep and 150 feet wide, from deep water in Chatham Roads along and around the tip of Harding Beach, and into Stage Harbor, and of a sand dike to close the existing breach across Monomoy Beach to the south of Morris Island. The channel includes extra widening at bends and at the U-turn off the tip of Harding Beach, and follows an alignment slightly different from the authorized project. The dike is approximately one mile long with side slopes of 1 on 20 on the ocean (east) side and 1 on 15 on the harbor (west) side, sloping from a centerline at elevation +15 above Mean Low Water. The slopes of the dike will be seeded with beach grass. In addition, sand fences are provided on top of the dike. The proposed plan is shown on Plate 1.

23. Use of the proposed dike for access to Monomoy Island is to be restricted and vehicles prohibited, as they will adversely affect the function of the dike and cause damage to the proposed beach grass and sand fences. This restriction is also desired by the U. S. Fish & Wildlife Service to protect the Wildlife Refuge.

DEPARTURES FROM PROJECT DOCUMENT PLAN

24. The principal departure of the proposed project plan, from the project document plan, consists of provision for a sand dike to close the existing breach and modification of the channel alignment to provide a straighter channel in the lower harbor. In addition, the channel bends in the vicinity of Harding Beach and the U-turn off the tip of Harding Beach are provided greater widths under the proposed plan to facilitate navigation.

OTHER PLANS INVESTIGATED

25. Several other plans have been investigated in addition to the authorized project and the proposed project plan. All plans studied are shown on Plate 2 and are described briefly below:

Plan A. - (Existing project) Continued maintenance of project as constructed in 1957, in accordance with the project document plan.

Plan B. - Same as Plan A. In addition, construction of mound or partial dike to shield the channel and to deflect the currents from the breach.

Plan C. - Same as Plan A. In addition, construction of sand dike to close the breach completely to protect the channel.

Plan C-modified. - (Recommended plan). Same as Plan C, except adjustment of channel alignment to eliminate certain bends in the lower harbor, and widening of bends and U-turn area.

Plan D. - Relocate channel across Harding Beach to provide a nearly straight channel into Stage Harbor.

Plan D-modified. - Same as Plan D. In addition, construction of sand dike to close the breach.

Plan E. - Same as Plan D. In addition, construction of a dike between Morris Island and the tip of Harding Beach.

Plan F. - Channel same as Plan C-modified. In addition, construction of dike between Nauset Beach and Monomoy Beach.

Plan F-modified. - Same as Plan D. In addition, construction of dike to extend the tip of Nauset Beach and dike off Monomoy Beach.

Plan G. - Same as Plan C-modified, except realignment of the approach channel to head directly from Chatham Roads to the U-turn off the tip of Harding Beach.

Plan H. - Same as Plan C-modified, except modification of the dike to include a confined opening at the natural breach channel, with stone fingers adjacent to it replacing portions of the sand dike.

26. Of the above, Plans A, C, C-modified, D and D-modified have been studied in detail, while the remaining were given only brief consideration. The results of a comparative study of the various plans are presented in the Appendix to this memorandum.

27. Selection of Plan C-modified as the most desirable means of maintaining the Federal project was, in part, based on the following considerations:

a. Closure of the breach is essential for the protection of the Federal channel into Stage Harbor. The existing breach, if left completely or partially open, will cause excessive shoaling and require frequent maintenance of the channel, particularly in the vicinity of the tip of Harding Beach.

b. Closure of the breach will again concentrate the tidal currents from Pleasant Bay in the natural channel off the tip of Nauset Beach, thus maintaining access to the Atlantic Ocean from Pleasant Bay.

c. Closure of the breach will help provide relative stability to the area and would tend to stabilize the bottom in the southerly portion of Stage Harbor and the shoals off Harding Beach, which is a requisite for the continued production of shellfish stocks and plant and animal organisms on which waterfowl feed.

d. Closure of the breach would also help to maintain the proper balance of water temperatures, salinities, and currents necessary for setting and growth of shellfish in Stage Harbor and west of Monomoy Beach.

e. A sand dike closing the breach will have the added effect of providing some limited littoral material, which would help nourish Monomoy Beach to the south, and, therefore, decelerate the occurence of other breaches in that area. However,

f. Complete closure of the breach will prevent the possibility of navigation from Chatham Roads to Pleasant Bay.

g. Adjustment of the channel alignment will provide a new channel, which is easier to navigate and is still generally along the route to which local boatmen are accustomed.

h. Relocation of the channel across Harding Beach would simplify navigation, particularly by visiting craft, and would provide a shorter channel into Stage Harbor.

i. Relocation of the channel across Harding Beach would reduce the protection presently being afforded to the harbor by permitting small waves from the Nantucket Sound to enter the harbor and to cause a "chop" condition. Since the harbor is presently practically landlocked, only waves generated within the Stage Harbor area exist now.

j. Relocation of the channel would require use of some of the town-owned beach and would render the easterly portion of Harding Beach inaccessible.

k. Relocation of the channel would alter the present and former balance of tidal currents in the area.

l. Plan C-modified has overwhelming local support and has received the official endorsement by the town of Chatham.

COST ESTIMATES

28. The estimates of cost for accomplishment of the proposed maintenance are based on unit prices prevailing in July 1962 and on quantities expected to be required if construction is undertaken in 1963. Annual charges are based on a project life of 50 years and estimates of maintenance represent the expected requirements during that period, expressed in terms of the annual average. The estimate of cost of the proposed maintenance plan is as follows:

First Cost	
Sand dike, 560,000 c.y. @ 0.80 $/c.y.	$448,000
Channel dredging, (accomplished by borrowing material for dike)	no cost
Grass seeding @ 0.05 $/s.f.	70,000
Sand fences @ 2 $/ft.	10,000
Contingencies @ 12%	63,000
Engineering and Design	14,000
Supervision and Administration	45,000
Total First Cost	$650,000

29. Project Cost. - The total project cost including costs for completed work is summarized below:

Construction in 1957	Federal	$259,000
	Non-Federal Cash Contribution	43,500
		$302,500
Investigation of excessive shoaling		12,500
Additional work required		650,000
	Total	$965,000

30. Annual Charges.

Interest and amortization	
Federal (@ 2.625% for 50 yrs.) (0.03614 x $921,500)	$33,300
Non-Federal (@ 3.5% for 50 yrs.) (0.04263 x $43,500)	1,900
Annual cost of channel maintenance (material dredged from channel to be placed on dike)	12,500
	$47,700

31. Estimates of cost for maintenance of the authorized project without construction of the dike include a total first cost of about $665,000 and total annual charges of $74,000, due to an expected high maintenance requirement of about $50,000, annually. The dike is justified by the annual saving of about $26,300 in estimated annual charges.

SCHEDULE FOR DESIGN AND CONSTRUCTION

32. Field investigations consisting of recent soundings, profiles, cross sections and land contours are available. Design studies have been completed in preparation of this memorandum. Predredging surveys, preparation of standard plans and specifications, invitation for bids and award of a contract could be accomplished within about 2½ months after funds are made available. Construction would require about 5½ months.

33. Delay in the accomplishment of the proposed work is expected to result in cost increases of up to $100,000 annually, because of the additional volume of fill required for the dike due to the continually enlarging breach.

34. Fund Requirements.

Allocated to date:	
For construction completed in 1957	$302,500*
For study of excessive shoaling and planning	12,500
Total Allocated	$315,000
Funds required for proposed maintenance:	
Completion of preconstruction planning	$ 12,000
Construction contract and overhead	638,000
Required to Complete	$650,000
Total Project	$965,000

* Includes $43,500 contributed by local interests.

OPERATIONS AND MAINTENANCE

35. No maintenance work has been accomplished since the existing project was constructed in 1957. Although moderate maintenance would have been required if Monomoy Beach had not breached, present maintenance requirements are estimated at 310,000 cubic yards for 1963 with the prospect of future annual maintenance requirements on the order of 50,000 cubic yards. A major reduction of maintenance requirements would result from maintenance by the proposed plan. With the breach closed by the dike future channel dredging requirements are estimated to average 12,500 cubic yards annually, and if this material placed on the dike no additional maintenance of the dike is anticipated. The future project maintenance cost is estimated at $12,500 annually.

BENEFITS

36. Restoration of Stage Harbor will produce benefits to the fishing commerce and recreational boating and will contribute to the preservation of the values of waterfront residential properties within the harbor and benefits from protection to shellfish habitat. Furthermore, other commercial activity in the area, not directly related to navigation, is expected to receive various secondary benefits. However, only those benefits which bear a direct tangible relation to the proposed project have been evaluated.

37. Fishing commerce statistics for the years 1956 to 1960 were supplied by the town of Chatham. These indicate the following anverage annual landings; and their ex-vessel values:

Cod & Haddock 1,410,000 lbs., $155,000; principally at Old Harbor.
Mackerel 222,000 lbs., $45,000; principally at Stage Harbor.
Squid 482,000 lbs., $95,000; principally at Stage Harbor.
Butterfish 232,000 lbs., $46,000; principally at Stage Harbor.
All Other Fish 112,000 lbs., $12,000; principally at Stage Harbor.
Quahogs $40,000; 90% at Stage Harbor.
Scallops $119,000; 90% at Stage Harbor.
Clams $5,000; 90% at Stage Harbor.
Mussells $2,000; 90% at Stage Harbor.
All Other Shellfish $2,000; 90% at Stage Harbor.
Lobsters 105,000 lbs., $63,000; 20% at Stage Harbor.
Oysters 4,500 bushels, $50,000; principally at Stage Harbor.
Plus about 250,000 lbs. of miscellaneous fish brought in party boats.

38. The above statistics indicate the total average annual fish landings at Stage Harbor to be worth about $400,000. An increase in this value of about $100,000 is expected over the 50 year project life, if the entrance channel is maintained. Since the operating costs to land the fish catch average about 60 percent of the gross ex-vessel value, the net annual value of the present catch is $160,000, and of the prospective future catch is $40,000.

39. Part of the present catch and about 1/2 of the prospective future catch could be landed at other Cape Cod ports if the entrance channel at Stage Harbor is not maintained. However, it is estimated that the inconvenience and extra expense to land the catch at other ports would result in a direct loss of 1/3 of the net value of the present catch, or $60,000 annually. For the prospective future catch, only about 1/2 could be realized if Stage Harbor is not available. On a straight line growth basis the annual value of a return increasing from zero to $20,000 (over 50 years at 2.625%) is about $8,000. This is also the annual value of the loss of prospective future catches if the channel is not maintained. The benefits from the fishing commerce are thus computed to be about $68,000 annually.

TABLE I. A RECREATIONAL CRAFT : PERMANENT LOCALLY BASED AT CHATHAM, MASS.
(From statistics furnished by the town of Chatham for the entire fleet of the town as of 1962)

TYPE OF CRAFT	LENGTH IN FEET	1962 NUMBER OF BOATS	DEPRECIATED VALUE		DAYS IN SEASON	IDEAL ANNUAL RETURN	
			AVERAGE	TOTAL		%	TOTAL VALUE
OUTBOARDS	10 - 20	800	$ 875	$ 700,000	105	13	$ 91,000
INBOARDS	10 - 20	57	2,000	114,000	105	10	11,400
CRUISERS	15 - 30	140	5,290	740,000	90	9	66,600
"	31 - 50	40	15,930	637,000	90	9	57,400
AUX. SAILS	15 - 30	3	4,500	13,500	90	9	1,200
"	31 - 40	3	18,000	54,000	90	9	4,900
"	41 - 60	1	220,000	220,000	90	8	17,600
SAILBOATS	10 - 20	175	760	132,500	90	12	15,900
"	21 - 30	8	1,800	14,400	90	11	1,600
CHARTER BOATS							
CRUISERS	21 - 35	2	4,000	8,000	180	8	600
"	36 - 50	7	6,710	47,000	180	8	3,800
TOTALS		1,236		$2,680,900			$272,000

Note: In addition, there are about 500 Rowboats valued at $57,500.

TABLE 2. RECREATIONAL CRAFT: TRANSIENT FLEET VISITING CHATHAM, MASS.
(From statistics furnished by the town of Chatham for the entire fleet visiting the town)

TYPE OF CRAFT	LENGTH IN FEET	1962 NUMBER OF BOATS	DEPRECIATED VALUE AVERAGE	DEPRECIATED VALUE TOTAL	AVERAGE DAYS IN PORT	EQUIVALENT LOCAL BOATS	IDEAL ANNUAL RETURN %	IDEAL ANNUAL RETURN TOTAL VALUE
			$	$				$
OUTBOARDS	10-20	250	1,000	250,000	10	23.8	13	3,100
CRUISERS	10-20	80	2,000	160,000	5	3.8	10	760
»	15-30	150	5,000	750,000	10	16.7	9	7,520
»	31-50	300	25,000	7,500,000	10	33.3	9	75,000
»	51-60	30	50,000	1,500,000	10	3.3	8	13,200
AUX. SAILS	15-30	58	3,680	213,400	10	6.4	9	2,120
»	31-40	80	12,000	960,000	10	8.8	9	9,500
»	41-60	175	25,000	4,375,000	10	19.4	8	38,800
SAILBOATS	10-20	30	800	24,000	5	1.7	12	160
»	21-30	15	1,930	29,000	5	0.8	11	170
TOTALS						118.0		$150,330

TABLE I-A RECREATIONAL CRAFT : PERMANENT LOCALLY BASED AT CHATHAM, MASS.
(From statistics furnished by the town of Chatham for the entire fleet of the town as of 1962)

TYPE OF CRAFT	LENGTH IN FEET	1962 NUMBER OF BOATS	DEPRECIATED VALUE		DAYS IN SEASON	IDEAL ANNUAL RETURN	
			AVERAGE	TOTAL		%	TOTAL VALUE
OUTBOARDS	10 - 20	800	$ 875	$ 700,000	105	13	$ 91,000
INBOARDS	10 - 20	57	2,000	114,000	105	10	11,400
CRUISERS	15 - 30	140	5,290	740,800	90	9	66,600
»	31 - 50	40	15,930	637,000	90	9	57,400
AUX. SAILS	15 - 30	3	4,500	13,500	90	9	1,200
»	31 - 40	3	18,000	54,000	90	9	4,900
»	41 - 60	1	220,000	220,000	90	8	17,600
SAILBOATS	10 - 20	175	760	132,500	90	12	15,900
»	21 - 30	8	1,800	14,400	90	11	1,600
CHARTER BOATS							
CRUISERS	21 - 35	2	4,000	8,000	180	8	600
»	36 - 50	7	6,710	47,000	180	8	3,800
TOTALS		1,236		$2,680,900			$272,000

Note: In addition, there are about 500 Rowboats valued at $57,500.

TABLE 2. RECREATIONAL CRAFT: TRANSIENT FLEET VISITING CHATHAM, MASS.
(From statistics furnished by the town of Chatham for the entire fleet visiting the town)

TYPE OF CRAFT	LENGTH IN FEET	1962 NUMBER OF BOATS	DEPRECIATED VALUE		AVERAGE DAYS IN PORT	EQUIVALENT LOCAL BOATS	IDEAL ANNUAL RETURN	
			AVERAGE	TOTAL			%	TOTAL VALUE
OUTBOARDS	10-20	250	$1,000	$250,000	10	23.8	13	$3,100
CRUISERS	10-20	80	2,000	160,000	5	3.8	10	760
»	15-30	150	5,000	750,000	10	16.7	9	7,520
»	31-50	300	25,000	7,500,000	10	33.3	9	75,000
»	51-60	30	50,000	1,500,000	10	3.3	8	13,200
AUX. SAILS	15-30	58	3,680	213,400	10	6.4	9	2,120
»	31-40	80	12,000	960,000	10	8.8	9	9,500
»	41-60	175	25,000	4,375,000	10	19.4	8	38,800
SAILBOATS	10-20	30	800	24,000	5	1.7	12	160
»	21-30	15	1,930	29,000	5	0.8	11	170
TOTALS						118.0		$150,330

40. Recreational boating is of increasing importance in the area. Tables 1 and 2 show the composition and values of recreational craft which make up the present locally based and transient fleets at Chatham. It is reported that, due to the present conditions at Stage Harbor, only about 1/3 of the fleets have been operating there, while the remainder 2/3 have been located or visiting in Old Harbor, Pleasant Bay and Ryder Cove. Applying these ratios to the statistics contained in the tables it may be estimated that about 400 boats are presently based in Stage Harbor valued at nearly $900,000 and have a potential ideal annual value of return of about $90,000. Similarly, the transient fleet visiting Stage Harbor may be estimated to be equivalent to about 40 locally based boats with a potential ideal annual value of return of about $50,000. The equivalent total fleet, therefore, has a total number of about 440 boats with a potential ideal annual value of return of $140,000.

41. Present channel conditions have restricted the use of recreational boats at Stage Harbor. If the channel is not maintained the present fleet in the harbor could receive less than 75 percent of the potential ideal annual return. Many of the larger craft would have to move to other harbors. Maintenance of the channel would permit these craft to stay at Stage Harbor and thus increase the annual return of the present fleet by 25 percent. The annual benefit would be $22,500 for the permanent fleet and $12,500 for the transit fleet.

42. The continued availability of Stage Harbor would also permit the fleet to expand. Because most of the southern Cape Cod ports are crowded and sheltered anchorage are limited, the fleet at Stage Harbor would double, if the channel is maintained. The annual return from the prospective fleet is therefore estimated to increase, on a straight line basis, to $90,000 for the local fleet and $50,000 for transients, during the project life. The equivalent annual values for these increases are about $37,000 and $20,000. This growth could be accommodated at other harbors only by additional improvements.

43. The above benefits from continued maintenance of the entrance channel at Stage Harbor are summarized below:

Present fish catch	$ 60,000
Prospective fish catch	8,000
Present Recreational boating	35,000
Prospective Recreational boating	57,000
	$160,000

44. Stage Harbor and its tributaries include more than 10 miles of protected shore frontage, with properties valued at about $4 million, inclusive of nearly $0.5 million in commercial harbor facilities. Abandonment of the present project would result in loss of the commercial investment and some reduction in the value of other properties. In addition, it will result in loss of about $200,000 worth of present annual bsuiness from servicing boats in Stage Harbor.

45. Additional benefits may also result from prevention of storm damage to local and transient commercial and recreational craft that would occur if the project is not maintained.

46. Other benefits are expected to be realized by fish and wildlife interests in the area, and by the shellfishing industry of Stage Harbor. The proposed dike would tend to stabilize the bottom in the southerly portion of the harbor and the shoals off Harding Beach, which is a requisite for the continued production of shellfish stocks and plant and animal organisms on which waterfowl feed. In addition, it will prevent the present transport and deposit of sand, caused by currents flowing through the breach, which inhibits setting of shellfish, establishment of aquatic plant life and production of animal organisms which are necessary to sustain other wildlife and provide resources for commercial and recreational use. It will also help to maintain the proper balance of water temperatures, salinities, and currents necessary for setting and growth of shellfish.

47. A sand dike closing the breach will have the added beneficial effect of providing some limited littoral material, which would help nourish Monomoy Beach to the south, and, therefore, decelerate the occurence of other breaches in that area. Preservation of Monomoy Beach and Island is essential for its continued use as a wildlife refuge.

48. The total annual benefits, estimated to accrue from the proposed project, amount to $160,000 in direct navigation benefits, and would probably exceed $250,000 if the benefits from preservation of the investment in commercial harbor facilities are included. However, the direct benefits of $160,000 annually are more than adequate to justify early undertaking of the proposed project. With annual charges at $47,700 the project benefit-cost ratio is 3.4 to 1.

RECOMMENDATION

49. It is recommended that the proposed plan for Chatham (Stage) Harbor, which provides for redredging the channel around Harding Beach with a protective dike to close the existing breach in Monomoy Island, as described herein and shown on Plate 1, be approved for maintenance of the project.

50. It is also recommended that the proposed work be approved for early maintenance. Early undertaking of the project is desirable because of the present rate of increase of the required volume to construct the dike, due to the continually changing conditions and enlargement of the breach, which is estimated to result in first cost increases of about $100,000 annually. In addition, the limited dredging undertaken recently by local interests is expected to serve the harbor only during the 1962 season, and additional work would be required shortly thereafter in order to keep the harbor in operation.

7 Incl
1. Plate 1 - General Map
2. Plate 2 - Alternatives Considered
3. Appendix - Project Design and Comparison of Alternatives
4. Plate 3 - Profiles
5. Plate 4 - Channel Shoaling Analysis
6. Plate 5 - Plan of Improvements
7. Plate 6 - Wind and Wave Data

CORPS OF ENGINEERS

U. S. ARMY

CHATHAM

OYSTER RIVER BOATYARD

TOWN DOCK

DUNBAR'S BOATYARD

MILL POND

OLD HARBOR

PLEASANT BAY

OYSTER POND RIVER

MONOMOY YACHT CLUB
STAGE HARBOR YACHT CLUB
CHATHAM MARINE RAILWAYS

BUD HENDERSON

MITCHELL R.

CHATHAM FISHERIES

STAGE HARBOR PIER

STAGE HARBOR

U.S. COAST GUARD

STATE DIKE (1957)

FORMER BREACH

STAGE HARBOR ISLAND

HARDING BEACH

MAINTENANCE NOT RECOMMENDED
FORMER LOCATION FEDERAL CHANNEL CONSTRUCTED IN 1957

MORRIS ISLAND

NAUSET BEACH

BREACH

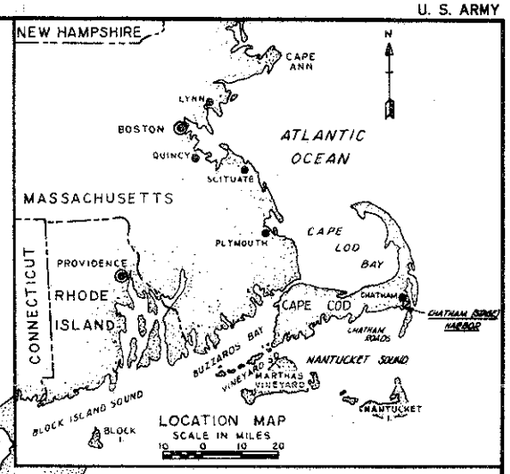
CHATHAM ROADS

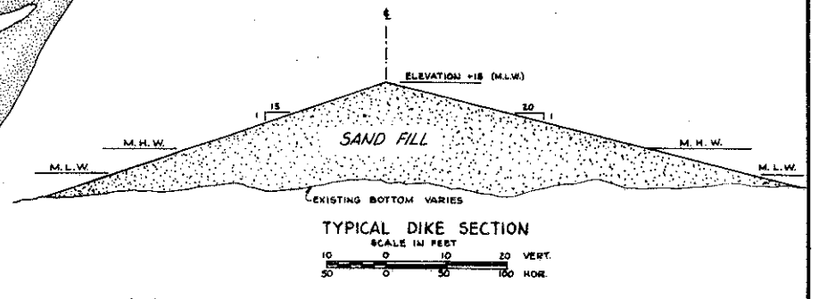
PROJECT MAINTENANCE ═══ RECOMMENDED
CHANNEL - 10 FEET DEEP
DIKE - 15 FEET HIGH - WITH BEACH GRASS AND FENCES

NANTUCKET SOUND

ATLANTIC OCEAN

MONOMOY BEACH





U.S. ARMY ENGINEER DIVISION, NEW ENGLAND
CORPS OF ENGINEERS, WALTHAM, MASS.

CHATHAM (STAGE) HARBOR, MASS.
GENERAL MAP
SCALE IN FEET
500 0 500 1000 1500 2000 2500

APPROVED
CHIEF, ENGINEERING DIVISION

SUBMITTED
CHIEF, ENGINEERING AND REPORTS BRANCH

CHIEF, PLANNING SECTION

PROJECT ENGINEER

DR BY AAV
TR BY AAV
CH BY AAV

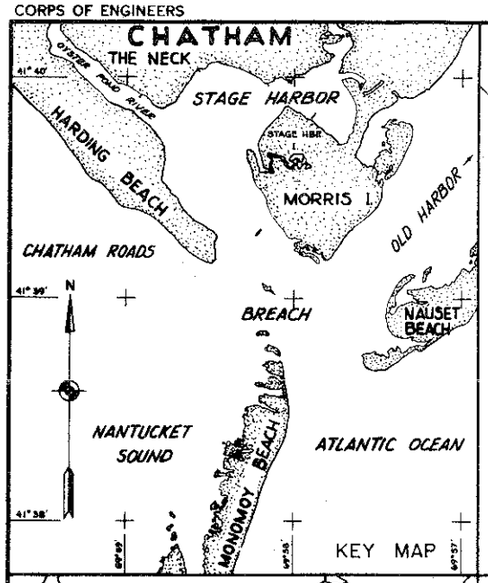
TO ACCOMPANY DESIGN MEMORANDUM DATED: 27 JULY 1962

FILE NO. Cm 33

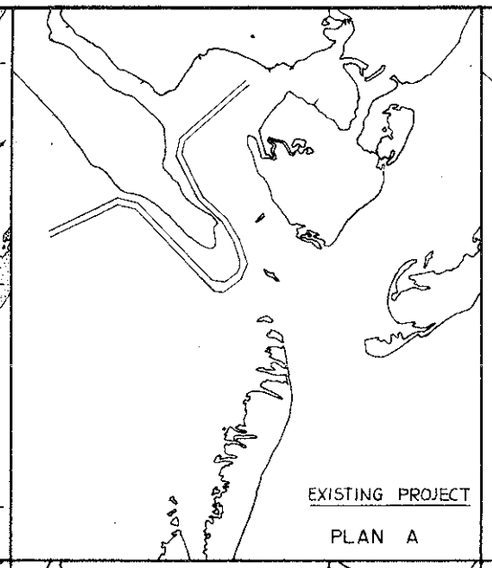
PLATE 1

CORPS OF ENGINEERS

U. S. ARMY

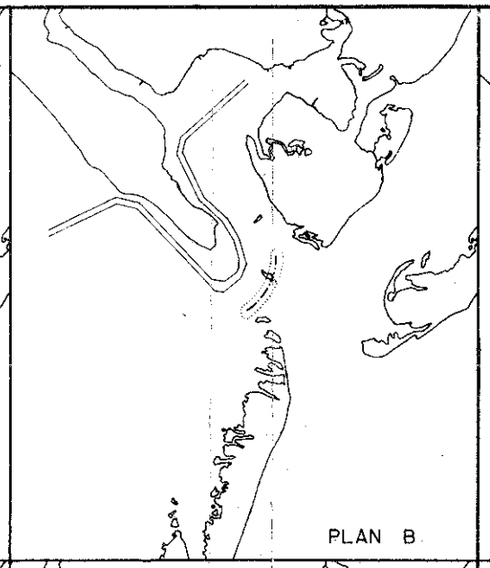


KEY MAP

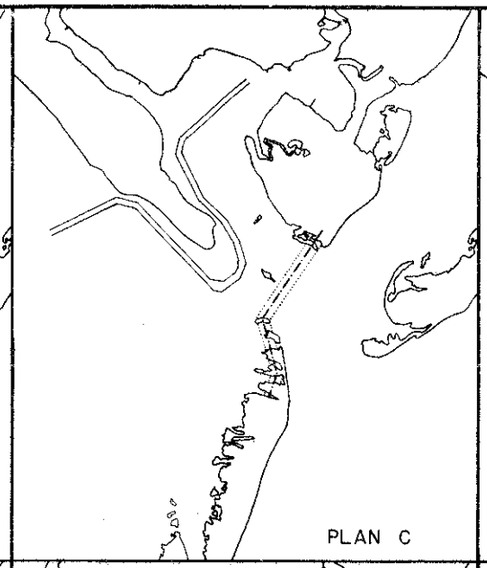


EXISTING PROJECT

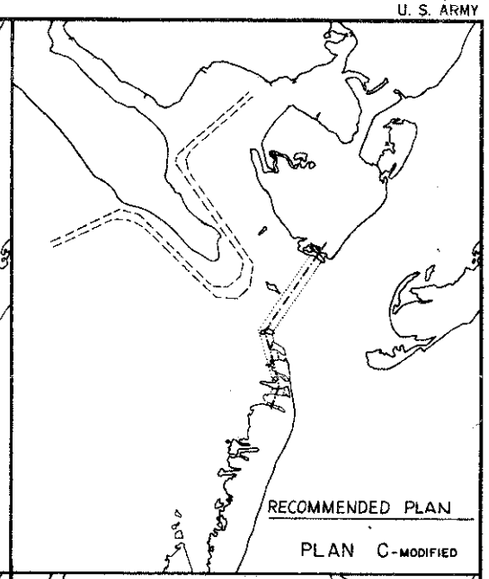
PLAN A



PLAN B

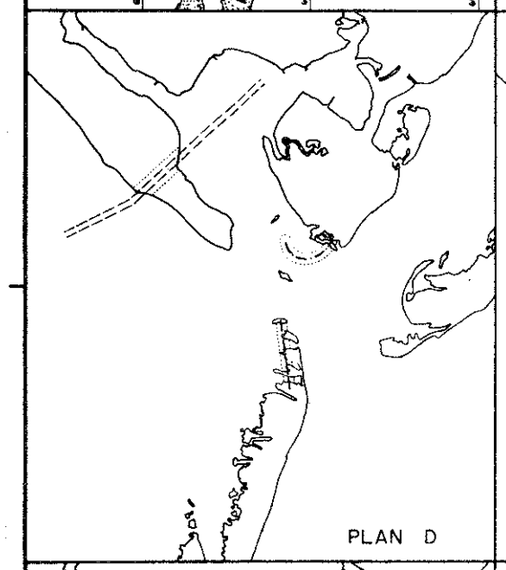


PLAN C

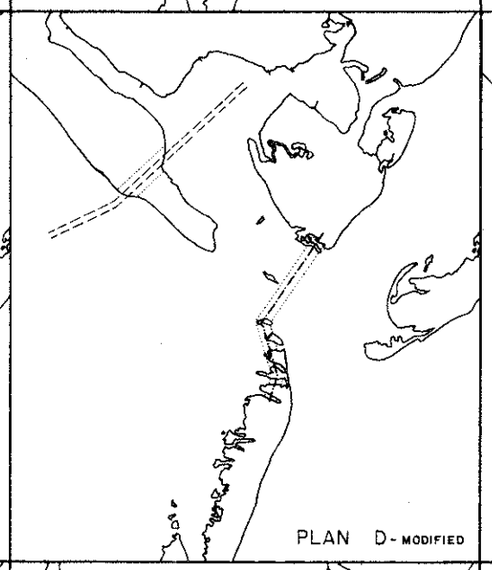


RECOMMENDED PLAN

PLAN C-MODIFIED



PLAN D



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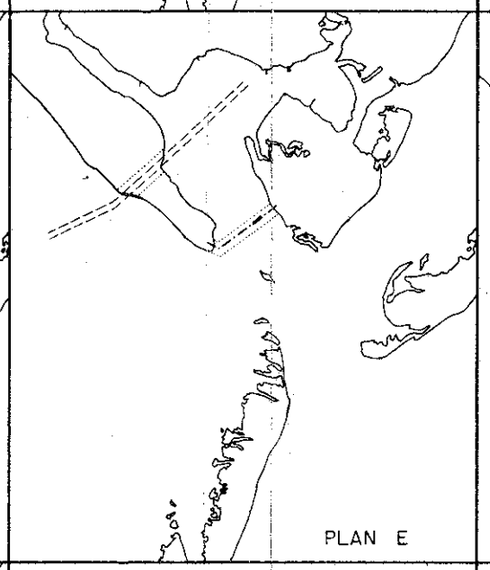
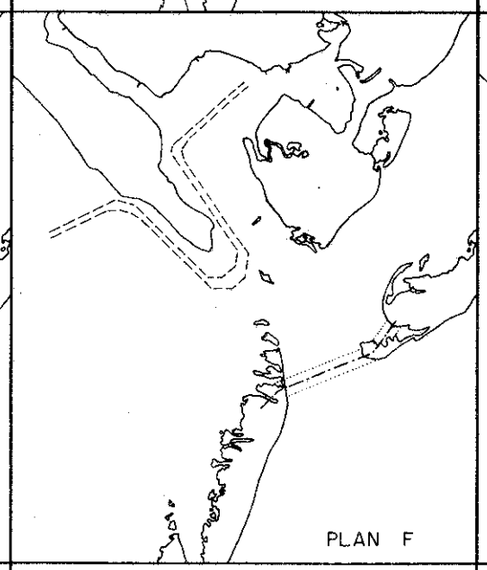
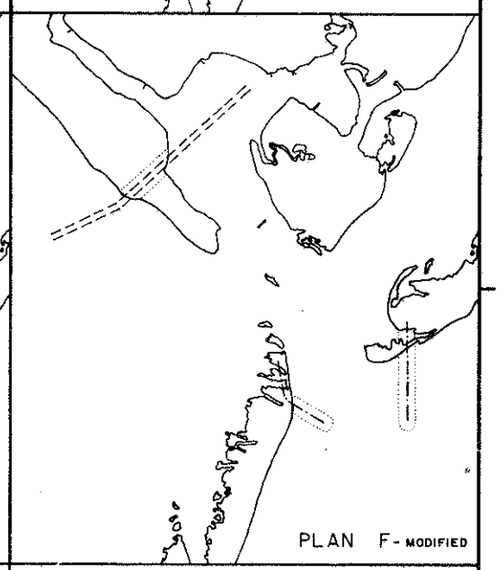


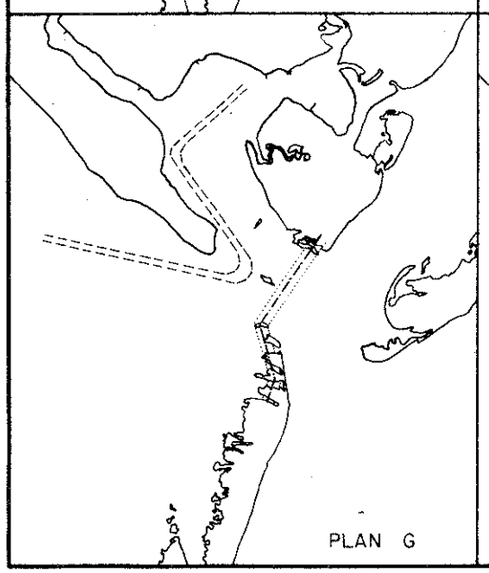
PLAN E



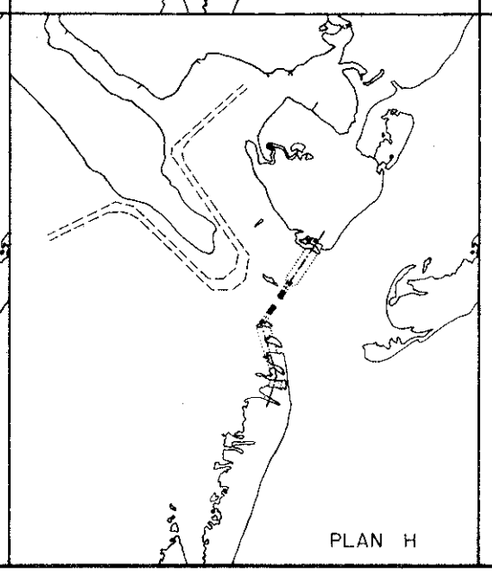
PLAN F



PLAN F-MODIFIED



PLAN G



PLAN H

LEGEND:

- EXISTING FEDERAL CHANNEL CONSTRUCTED IN 1937
- PROPOSED 10-FOOT CHANNEL
- NEW MEAN HIGH WATER LINE
- CENTERLINE OF PROPOSED SAND DIKE
- STONE DIKE

U.S. ARMY ENGINEER DIVISION, NEW ENGLAND
CORPS OF ENGINEERS, WALTHAM, MASS.

CHATHAM (STAGE) HARBOR, MASS.
ALTERNATIVES CONSIDERED

SCALE IN FEET

2000 0 2000 4000 6000

APPROVED: [signature]
CHIEF, ENGINEERING DIVISION

SUBMITTED: [signature]
CHIEF, PLANNING AND REPORTS BRANCH

[signature]
CHIEF, RIVER AND HARBOR SECT

[signature]
PROJECT ENGINEER

DR BY AAV
TR BY AAV
CH BY AAV

TO ACCOMPANY DESIGN MEMORANDUM DATED: 27 JULY 1962

FILE NO. Cm 34

PLATE 2

DESIGN MEMORANDUM ON
CHATHAM (STAGE) HARBOR, MASSACHUSETTS

APPENDIX - PROJECT DESIGN
AND COMPARISON OF ALTERNATIVES

1. Summary. - Engineering and economic studies were made of various alternatives to determine the most feasible and economic solution to the problem of maintaining the entrance channel at Chatham (Stage) Harbor. This appendix contains the result of these studies together with a discussion of the effectiveness of several alternative plans. The studies indicate that continued maintenance of the present entrance channel would not be practical, unless the breach across Monomoy Beach is sealed off with a dike.

2. General. - This appendix has been limited in scope to certain alternative plans. These plans have been studied in detail, their effectiveness analysed and their relative advantages and disadvantages evaluated in order to determine the most feasible and economic solution. In addition, certain other plans were considered, but in lesser detail.

3. This appendix also contains the results of various engineering studies, which were undertaken in order to permit a better understanding of the problems in the project area, the shore processes and other factors, as they relate to the various plans. The results of previous studies reported in other reports have not been repeated, although these are considered to be valuable and have been used in the present analysis of the problems in the area.

4. The plans studied in this appendix have been developed to cope with the immediate problems affecting the project in this area, and are not intended as long-term solutions of the overall problems of coastal Chatham.

5. The following plans were studied in detail:

PLAN A. Maintain the present channel as constructed in 1957.

PLAN C. Same as Plan A. In addition construct a 5,000' dike to close the breach.

PLAN C-modified. Same as Plan C, except re-align the channel to eliminate certain bends in the lower harbor and widen others.

PLAN D. Construct a new relocated channel across Harding Beach.

PLAN D-modified. Same as Plan D. In addition, construct a 5,000' dike to close the breach.

The following plans were also considered:

PLAN E. Same as Plan D. In addition, construct a dike across the mouth of Stage Harbor.

PLAN G. Same as Plan C-modified, except also re-align the approach channel to head directly to the mouth of the harbor across the flats.

PLAN H. Same as Plan C-modified, except the dike would be constructed with stone fingers adjacent to the natural breach channel, leaving a confined opening.

6. Statement of the Problem. The problem at Chatham (Stage) Harbor and its channel is associated with shore processes in the area. Monomoy Beach, a sand barrier joining Monomoy Island to Morris Island, was breached in 1956. By 1961 the breach was deepened, widened and made a continuous waterway. Since 1961 the breach has continued to enlarge at a more rapid rate. Sediment being moved by the tidal currents through and from the breach area has been depositing in the vicinity of Harding Beach and shoaling rapidly the Stage Harbor channel at that location, thus making the channel unusable. Although the ebbing currents from the harbor have apparently decelerated shoaling activity within the harbor, the shoal front has continued to advance west along the southerly shore of Harding Beach, thus threatening the approach channel.

7. A related problem concerns the access channel from the Atlantic Ocean to Chatham Old Harbor and Pleasant Bay. This is a natural channel formed by the currents between Nauset Beach and the mainland, Morris Island and Monomoy Beach, and is located off the tip of Nauset Beach. Since occurrence of the breach, part of the tidal flow from Pleasant Bay has been increasingly diverted through the breach into Stage Harbor and Chatham Roads, resulting in some

reported shoaling of the ocean access channel. Study of this channel is not within the scope of the present investigation. However, it is important to recognize that the problems affecting this and the Stage Harbor Channel are interrelated and have a common origin, i.e. the breaching of Monomoy Beach.

8. A similar problem existed in the area when the sand barrier joining Morris Island to the mainland of Chatham had been breached resulting in excessive shoaling of Stage Harbor. This condition was the subject of a cooperative beach erosion control study and later, in 1957, resulted in the construction of a sand dike closing the breach. That project was undertaken entirely by local interests and the Massachusetts Department of Public Works. The two breaches bear certain important differences. The breach north of Morris Island was confined in width because of high ground on the mainland and Morris Island, where the present breach is bordered to the south by Monomoy Beach, a low sand spit with numerous other potential breach areas. In addition, the former breach was discharging into Stage Harbor directly, where the present breach is located near the mouth of the harbor and flows into both Stage Harbor and Chatham Roads.

9. The beach erosion report states that a breach at Monomoy Beach had occurred during the 1938 hurricane, it was reopened and widened by the hurricane of 1944 and subsequently healed itself by natural means. A small breach had recurred during the winter of 1955-56, which, it is reported, the Fish and Wildlife Service was attempting to close by constructing small dikes. In 1961, and at present, the breach has assumed large proportions with the deleterious effects on the Stage Harbor Channel, due to shoaling, in direct relation. The currents, which have developed in the vicinity, have, in addition, caused the tip of Harding Beach to erode.

10. In order to cope with the problem temporarily, and to provide access to Stage Harbor at least during the Summer of 1962, the Town of Chatham undertook dredging of an 8-foot channel around the tip of Harding Beach, at their own expense. This local project was completed by mid-June 1962.

11. Winds and Waves. Study has been made of the wind records at Nantucket, Massachusetts, for the periods August 1952 - July 1957 and August 1958 - July 1960, and of a 9-year summary of winds 30 miles per hour or higher, which have been compiled by the Army

Engineers. The above will be contained in the Beach Erosion Report at Falmouth, Massachusetts. In addition, the wind and wave data contained in the Chatham Beach Erosion Report were given consideration.

12. Winds are of importance in the present study both as wave generators and as sediment carriers overland. The function of winds as overland sediment carriers and their characteristics and behavior in this function have particular applications and implications relative to any plan which involves cutting a channel across Harding Beach. A dike to close the present breach at Monomoy Beach would also be affected by winds, but to a smaller degree.

13. Harding Beach is oriented in a northwest to southeast direction. Winds from the northwesterly direction (WNW, NW and NNW) account for 24.5% of the total wind movement, while winds from the southeasterly directions (ESE, SE and SSE) account for only 12.0% of the total wind movement, if winds of all speeds are included. However, for winds of over 30 m.p.h. alone, the above directions account for 14.5% and 8.5% of the wind movement, respectively. Uniform distribution of wind movement would have resulted in 18.75% for the above.

14. The above indicate that there is a definite predominance of the northwesterly winds, with a movement strength of nearly twice that of the southeasterly winds. A channel across Harding Beach would divide it into two disproportionate pieces; the piece to the northwest being 5 to 6 times larger than the piece to the southeast. Considering the combined effect of the greater movement strength and the larger area northwest from the channel, it may be estimated that wind-driven sand along Harding Beach would be encroaching upon the new relocated channel 10 times faster from the northwest than from the southeast. Sand fences should, therefore, be designed to intercept a comparable ratio of volumes, in order to operate efficiently, or be provided at least only along the northwesterly side of the new channel.

15. Monomoy Beach and a dike across the breach are subject to north-northeasterly and south-southwesterly winds (N, NNE, and NE and S, SSW, and SW, respectively). Of the total wind movement 16.2% are contributed by the north-northeasterly winds and 22.4% by the south-southwesterly. However, for winds of over 30 m.p.h. alone, the above directions account for 36.5% and 7.2% of the wind movement, respectively. Examination of the distribution of wind duration by

speed and direction reveals that there is a marked change in the predominance; winds from the south-southwest have advantages over the winds from the north-northeast for wind speeds between 8 and 18 m.p.h., while the reverse holds true for speeds between 25 and 46 m.p.h.

16. Movement of sand by the wind, or wind deflation, is not easily computable, since little research has been done on the subject. It appears, however, that fine sand is moved by winds of over 9 m.p.h. The rate of sand drift bears a relation to the square of the wind velocity. On this basis, comparing the sum of the products of duration times the square of the average wind speed, for each wind speed grouping (Beaufort scale) over 8 m.p.h., the net drift should be in a north-northeasterly direction, with a rate at about 22% higher than the overall level of deflation. Furthermore, because of the partial shelter provided by Morris Island, winds from the south-southwest would have an additional advantage.

17. Estimates of rates of deflation for Harding Beach and for a dike across the breach at Monomoy Beach appear in other parts of this appendix.

18. The functions of winds in generating waves has been the subject of considerable research. However, presently available methods of wave forecasting do not cover wave generation in transitional water, which is the case in the Nantucket Sound Basin. It was, therefore, necessary to make wave estimates using both deep and shallow water wave forecasting methods and to reconcile between the two.

19. The effective fetch within the Nantucket Sound basin is dependent upon the average wind speed and the duration of the design storm. Where the fetch distance is not limited by land, the product of wind speed and duration establish an effective fetch field, (F_f). On this basis, a series of formulae were developed for the effective fetch, (F_e), in the Nantucket Sound applicable to the Harding Beach area. These are listed below:

<u>South-Southwest Direction:</u>

For F_f over 29 naut. miles; $F_e = 12.3 + .123F_f$

For 26 under F_f under 29 n. m.; $F_e = 8.8 + .244F_f$

Southwest Direction:

For F_f over 100 naut. miles; $F_e = 16.8 + .131\ F_f$

For 33 under F_f under 100 n.m.; $F_e = 14.5 + .155\ F_f$

For 29 under F_f under 33 n.m.; $F_e = 13.7 + .179\ F_f$

For 26 under F_f under 29 n.m.; $F_e = 9.3 + .332\ F_f$

West-Southwest Direction:

For F_f over 100 naut. miles; $F_e = 15.2 + .119\ F_f$

For 36 under F_f under 100 n.m.; $F_e = 12.6 + .145\ F_f$

For 30 under F_f under 36 n.m.; $F_e = 11.6 + .171\ F_f$

For 26 under F_f under 30 n.m.; $F_e = 7.0 + .328\ F_f$

20. The 9-year summary of winds over 30 m.p.h. was analysed and adjusted on the basis of an assumption that 10% of the winds of each adjoining direction are part of the central storm, which had shifted, and do not, therefore, constitute separate storms. The pertinent data from the above summary and the adjusted figures are listed below:

	SSW Sum/Adj.	SW Sum/Adj.	WSW Sum/Adj.
Number of occurrences	4/3.2	4/3.2	11/8.8
Average duration (hours)	5/6.6	11/15.0	9/11.0
Average wind speed (m.p.h.)	32/32.6	34/33.8	33/33.2
Average wind speed (knots)	/28.3	/29.3	/28.8

21. On the basis of the above, the effective fetch, in nautical miles, is estimated to be 29.4, 59.3 and 46.0, using the data from the summary, and 35.3, 74.4 and 52.9, using the adjusted figures, for the SSW, SW and WSW directions, respectively.

22. The depth at the end of fetch and the slope of the bottom along the fetch are very difficult to determine in the Nantucket Sound basin because of the irregularity of the contours and the

rapid change in depth. The average depth over the effective fetch is equally difficult to evaluate. No simple method is available for determining accurately depths and slopes in an irregular fetch area. A method developed and having been used satisfactorily in the past by the writer is similar to the method used for determing the effective fetch and consists of determining values for each sector of the fetch spectrum and taking a weighted average on the basis of the relative fetch length of each sector. However, since there exists a condition of transitional water in the Nantucket Sound basin, it was not considered necessary for this study to apply the above method in order to determine accurately the effective fetch depths and bottom slopes. Rough estimates were made for use in the methods for forecasting shallow water waves, which were used in turn to check the deep water wave forecasts.

22. Irregularities in the bottom contours affect not only the accuracy of wave forecasting, but also cause refraction of the waves and contribute to significant reductions in the height and energy of waves reaching the project area.

23. Forecasts of waves by the deep water method indicate heights of 7.1', 9.7' and 8.5' for the SSW, SW and WSW directions, respectively. The corresponding periods and wave lengths are 6.4"/210', 7.8"/312' and 7.2"/265'. The above are found to be in reasonable agreement with wave forecasts by Bretschneider's shallow water method. However, some discrepancies were found with the shallow water method of Thysse and Schijf, probably because of the inaccuracies in the estimates of average depth.

24. Refraction diagrams were prepared for waves approaching the project area from the three principal directions in the Nantucket Sound basin. Analysis of the refraction patterns indicates that reduction of more than five times of the wave heights reaching the project area is probable. The cooperative beach erosion control study of the southerly shore of Cape Cod (Chatham to Point Gammon), dated August 26, 1941, stated that "Limited wave observations indicate that the prevailing direction of travel is from the southwest, that the height is seldom over 3 feet and the length seldom over 50 feet". This substantiates the findings of this study.

25. The refraction patterns also indicate that a channel across Harding Beach would permit only very small waves to pass into Stage Harbor. These would generally be of the "chop" type and only on rare occasions would they become of significant size, probably still under one-foot in height.

26. Waves from the Atlantic Ocean side have been compiled by hindcast methods and appear in wave rose form in other reports.

27. Tides and Currents. - Tides and currents have an important bearing on the problems in the study area. Due to differences in tide between the Atlantic Ocean and Nantucket Sound, excessive tidal currents are flowing in the breach area causing the serious erosion and shoaling conditions.

28. Tidal and current measurements have been made and reported in the cooperative beach erosion control report of July 27, 1956, pertaining to the previous breach north of Morris Island. Since conditions are different at the present time, caution should be exercised in using the above information.

29. Current measurements had also been made and reported in the cooperative beach erosion report of August 26, 1941. These measurements were made across the mouth of Stage Harbor and have some applicability at present.

30. In order to obtain additional information and to supplement the above, tidal observations and current measurements were undertaken in conjunction with the present study. These are shown on Figures 1 and 2. Because of an apparent error in the reference elevation of at least one of the three stations used, only the shape and range of the tidal curves was considered to be usable.

31. The current measurements made near the mouth of the Oyster Pond River, as shown on Figure 2, indicate that the existing velocities are within the scour-free range, and because of prior diffusion their effect on the channel will be limited.

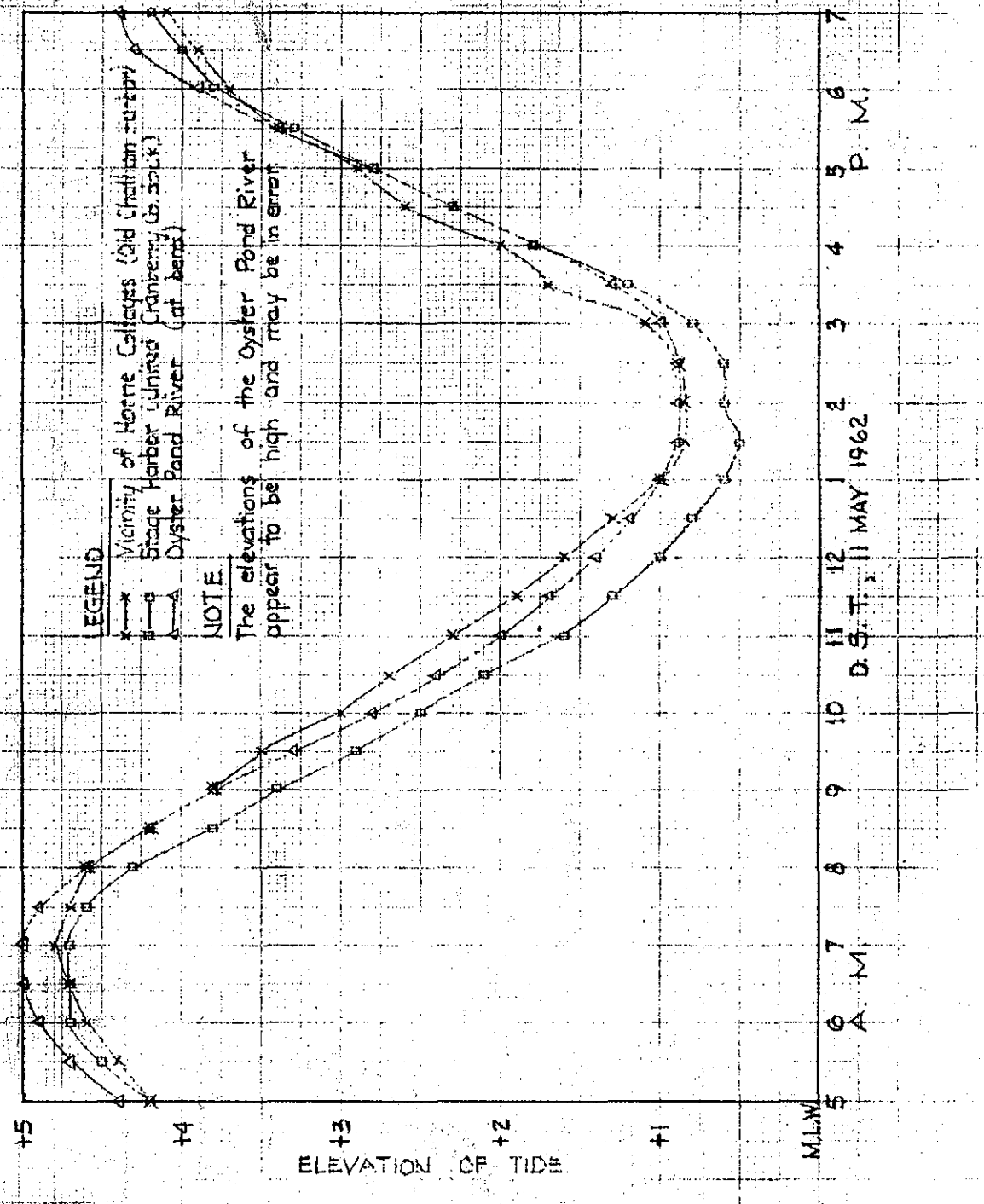
32. The U.S.C. & G.S. Tide Tables list mean and spring ranges for specific areas in the vicinity of the project. These have apparently been based on data prior to the existence of any breach. The 1956 beach erosion report made an analysis of tides which include the effects of the previous breach. The values from the above two sources are listed below: (Tide Table / 1956 report)

CORPS OF ENGINEERS U. S. ARMY

STUDY OF CHATHAM (STAGE) HARBOR CHANNEL . CHATHAM, MASS.

TIDAL OBSERVATIONS

11 MAY 1962



A.A. VULGAROPULOS ♦ CONSULTING ENGINEER

WALTHAM, MASS.

FIGURE 1

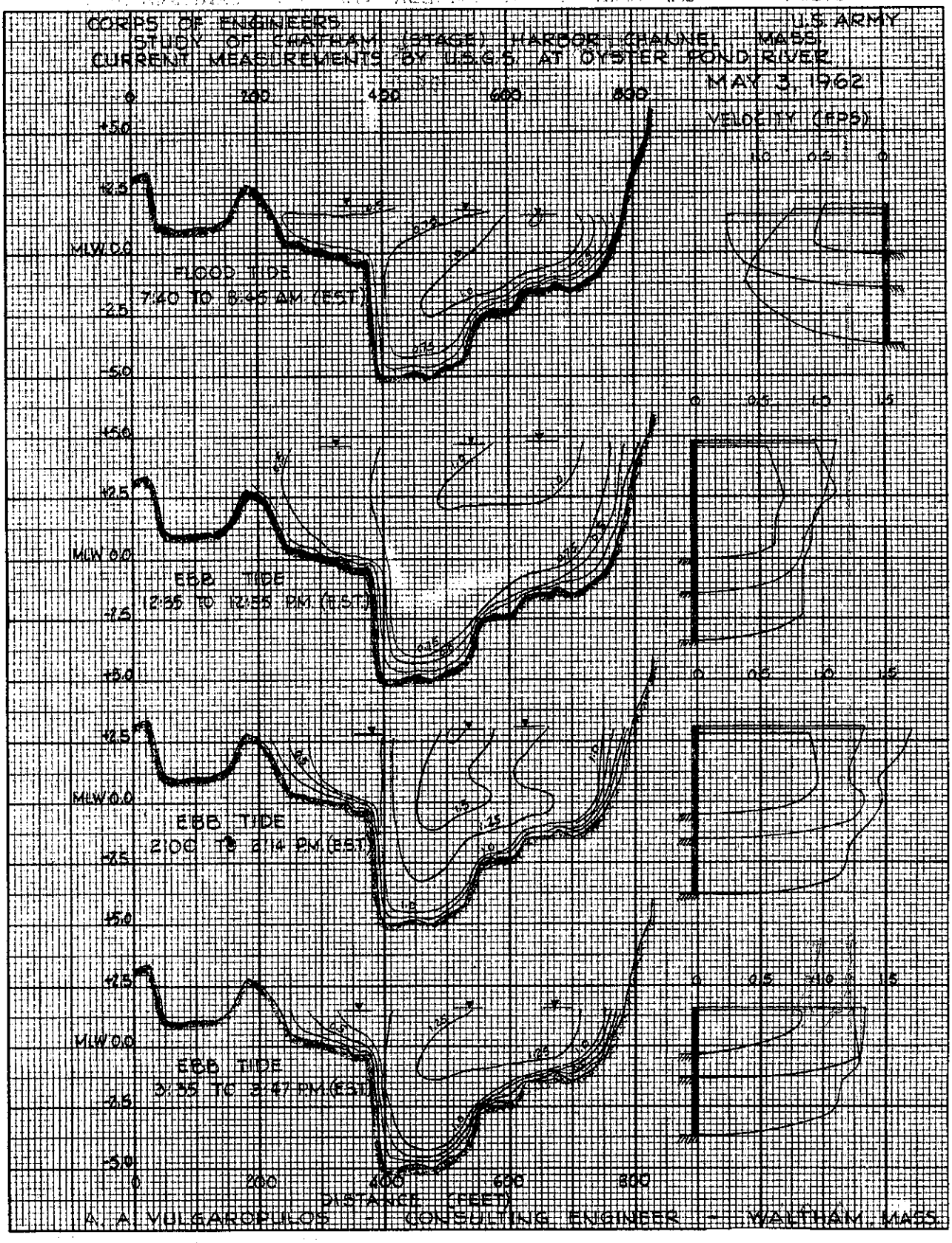

CORPS OF ENGINEERS U.S. ARMY
STUDY OF (WATERWAY (STAGE) HARBOR (CHANNEL MASS.
CURRENT MEASUREMENTS BY U.S.C.G.S AT OYSTER POND RIVER
MAY 3, 1962
VELOCITY (FPS)
FLOOD TIDE
7:40 TO 8:45 AM (EST)
EBB TIDE
12:55 TO 12:55 PM (EST)
EBB TIDE
2:00 TO 2:14 PM (EST)
EBB TIDE
3:55 TO 3:47 PM (EST)
MLW 0.0
DISTANCE (FEET)
A. A. VULGAROPULOS - CONSULTING ENGINEER - WALTHAM, MASS.

FIGURE 2

Station or Place	Mean Range	Spring Range	Lag (min.)
Chatham outer coast @ Nauset	6.7/6.6	7.8/8.1	- / -
Pleasant Bay	3.5/	4.1/	105/
Chatham Old Harbor	3.9/4.5	4.7/5.2	100/60
Monomoy Point & Island	3.7/4.1	4.3/4.7	10/25
Stage Harbor	3.9/4.1	4.7/4.7	25/40

33. The tidal conditions under the present breach south of Morris Island are not reflected directly by either of the above. The changed position of the breach, its size, as well as the changed position of Nauset Beach, would be expected to produce somewhat different effects. Generally, however, short of a special detailed study, it is expected that the tidal ranges would be nearer to the condition of the previous breach, except that the phasing or lag would be different. In particular, it is anticipated that the lag under the present breach would be smaller between Stage Harbor and Chatham Roads, than it was under the conditions of the previous breach.

34. Several tidal computations were made in connection with the present study in order to determine the existing conditions and the effects of the various alternative plans considered.

35. Estimates have been made of the water areas at low and high water for the pertinent estuaries in the project area. Stage Harbor has a water area ranging between 19 and 28 million square feet, including 6 to 9 million s.f. in the Oyster Pond and River tributary and 2 to 3 million s.f. in the Mitchell River and Mill Pond tributary. Pleasant Bay, above latitude 41°42', has a water area ranging between 166 and 249 million s.f., and inclusive of the Chatham Old Harbor to latitude 41°39' the water area amounts to 213 and 317 million s.f. for low and high water, respectively.

36. The volumes of water which flow in and out of the above estuaries during a tidal cycle may be estimated to be about 95 million cubic feet for the mean range and 110 million c.f. for the spring range in Stage Harbor, and approximately 1.1 and 1.3 billion c.f. for Old Harbor and Pleasant Bay.

37. Analysis of the above, together with the steepness of the tidal curves, can be a basis for estimating the tidal discharge rates. However, because of the proximity of the discharge volumes for the mean and spring ranges, it was not considered necessary to make separate computations for the two conditions. A difference in the discharge rate has been found to be more significant between the various stages of tide, particularly as it affects the magnitude of the velocities. For example, a smaller discharge at a lower stage could be capable of producing higher velocities, due to the reduction in the cross-sectional area of the inlet-outlet channel.

38. The rates of tidal flow in Stage Harbor were estimated to vary between 6200 and 7600 cfs for various stages of tide, other than the periods of relative slack. The comparable rates of flow for the Old Harbor and Pleasant Bay have been estimated to vary between 70,000 and 110,000 cfs.

39. Tidal velocities near the mouth of Stage Harbor have been computed to vary from 0.9 to 0.7 fps over the entire cross-section under present conditions, or when this is the only inlet to the harbor. These mean velocity values incorporate higher velocities in the channel section, due to the variation in the sectional hydraulic radii. On this basis, velocities in the channel portion of the cross-section were estimated to vary between 1.0 and 1.3 fps for different stages of tide. In addition, non-uniformity and bends in the channel may be expected to contribute to local increases in velocity. The current measurements made near the mouth of Stage Harbor in 1938 and reported in the beach erosion report of 1941 show the average velocity to vary up to about 1.0 fps, and discharge to vary up to about 8 - 9,000 cfs. The estimates made above appear to be in general agreement with the current measurements.

40. If a channel is constructed across Harding Beach and the existing inlet to the harbor is allowed to remain open, the velocities in the channel and at the natural mouth will be dependent on the distribution of flow between the two openings. This distribution is in turn dependent on the size and shape of the new relocated channel, assuming that the cross-section of the natural mouth will remain approximately the same. It is estimated that for a channel 150' wide the velocities will be about as follows for different side slopes:

		1 on 3	1 on 10	1 on 20
Relocated channel:	average (fps)	1.3	1.1	0.9
	at center "	1.4	1.2	1.0
Natural mouth:	average "	0.5	0.5	0.4
	at center "	0.7	0.7	0.6

41. If a relocated channel across Harding Beach is the only inlet to Stage Harbor, which would be the case in the event a dike is constructed across the natural mouth, the velocities have been estimated to be as follows:

		1 on 3	1 on 10	1 on 20
Relocated channel:	average (fps)	3.1	2.2	1.5
	at center "	3.2	2.4	1.8

42. If the channel is relocated across Harding Beach and, in addition, the breach to the north of Morris Island was allowed to remain open, while the present breach was diked off, then the velocities in the relocated channel would increase substantially to reflect the additional flow being diverted through Stage Harbor. On the basis of varying head loss assumptions, the following low and high velocity estimates have been made:

		1 on 3	1 on 10	1 on 20
Relocated channel:	low est. (fps)	3.0	2.7	2.5
	high est. "	4.0	3.5	3.3

43. Tidal velocities between Morris Island and Nauset Beach, to pass the flows discussed previously, are estimated to range up to about 5 fps.

44. Materials and Shoaling. - Surface samples on the ocean side of Nauset Beach and Monomoy Beach had been obtained and reported in the beach erosion report of 1956. Additional samples were obtained for the present study at Oyster Pond River, Harding Beach and the present breach, as well as at the easterly shore of Morris Island. The analysis of these samples is tabulated in this report.

45. The materials appear to be generally medium to fine sand, with finer materials at certain locations and coarser at others. The median diameters vary from 0.28 to 1.3 mm. and average about 0.56 mm.

46. At Oyster Pond River the medium to fine sand bottom appears to be susceptible to little or no scouring action due to the tidal currents observed.

47. The medium to fine sand of the berm and dune areas of Harding Beach appears to be subject to deflation by the winds. Discussion of the influence of the winds was presented in the appropriate section. Volumetric estimates of deflation on Harding Beach indicate a southeasterly movement of about 150 c.y. per foot of beach, annually, which is partly counteracted by a movement in the opposite direction of about 75 c.y./ft.

48. A sand dike constructed across the present breach with materials similar to those sampled may be expected to be subject to deflation rates of 135 and 110 c.y./ft./yr. in the north-northeasterly and south-southwesterly directions, respectively. However, because of the partial shelter afforded by Morris Island, the deflation rates in the south-southwesterly direction may be expected to be reduced. The estimates, as shown above, will probably be applicable to Monomoy Beach and Island, as well, provided that the materials are substantially the same.

49. All of the above estimates of deflation have been based on the state of vegetation-free surface of sand. The presence of beach grass will contribute to substantial deceleration of the rates of deflation and should, therefore, be considered for the banks of a relocated channel across Harding Beach and for the slopes of a dike to close the breach. In addition, sand fences will help to reduce deflation and to arrest some of the material during its movement.

50. Tidal currents in the present natural mouth of Stage Harbor are sufficiently small to be scour-free. Tidal currents in a relocated channel would also be within the safe scour-free limits provided that the natural mouth is not diked off and that no opening of significant size is permitted north of Morris Island.

51. Since a relocated channel across Harding Beach will be subject to some wave action, in addition to the tidal currents, it is considered desirable to provide flat beach slopes for its banks in order to minimize the scour potential. If scour occurs in the relocated channel, the material will most likely deposit on either end of the channel thus interfering with navigation, and probably requiring frequent maintenance dredging of small quantities. Slopes flatter than one on ten (1 on 10) are considered essential for the cut portion of a new channel.

ANALYSIS OF SAND SAMPLES

Number and Location	Median Diameter in MM.	Character of Material in Percent		
		Fine Sand (.074-.42MM)	Medium Sand (.42-2.0MM)	Coarse Sand (2.0-4.7MM)
Harding Beach (vicinity of Station Harding West)				
S-1 MLW south	1.3	1	73	21
S-2 Berm "	.46	38	62	0
S-3 Dune "	.66	10	90	0
S-4 Dune north	.57	30	56	6
S-5 Berm "	.55	19	79	1
S-6 MLW "	.51	20	77	1
Oyster Pond River (1500 feet upstream of mouth)				
S-7 MLW south	.58	13	83	1
S-8 center	.49	34	56	5
S-9 MLW north	.48	34	61	2
Chatham Roads Flats (southeast of approach channel)				
S-10 midway	.36	81	18	0
S-11 outer end	.50	29	71	1
Morris Island (near center of easterly shore)				
S-12 Berm	.55	21	79	0
S-13 MSL	.92	25	50	13
S-14 Elev. -6' MLW	.41	55	29	2
Breach at Monomoy Beach (position of samples in relation to S-19)				
(S-19 is located 3500' from Station Harding East and 2100' from Station Sand/1962)				
S-15 NNW 1450'	.43	49	51	0
S-16 NNE 1050'	.50	21	79	0
S-17 ENE 1500'	.58	22	78	0
S-18 WNW 1050'	.42	50	48	2
S-19 Center	.47	39	51	7
S-20 ESE 1000'	.64	3	95	2
S-21 SSW 1050'	.28	84	16	0
S-22 SE 1300'	.63	6	93	1

52. The tidal differences between the Atlantic Ocean and the Nantucket Sound have been generating currents in the breach area of sufficient strength to be causing considerable scour in that area and deposition of the material in the navigation channel and other area in the vicinity of Harding Beach. The effects have been adverse to both navigation and to shellfish beds in the area. Because of insufficient tidal information, it was not possible to evaluate the strength of currents in the breach area. It would appear, however, that these currents may be presently of the order of 5 to 7 fps.

53. Southward growth of Nauset Beach will tend to reduce the tidal differential across the breach and, thus, decelerate the scouring and shoaling rates. If no action is undertaken, it may be expected that, eventually, as the tidal differential is reduced and the breach area is enlarged, a state of relative equilibrium or stability would be achieved. This would again be disturbed when, and if, Nauset Beach is breached to the north and/or disintegrated. In that eventuality, it is probable that an opening at, or near, the present breach will tend to seal itself by natural means.

54. Diversion of the tidal flow partly through the breach has meant a corresponding reduction in the flow between Nauset Beach and Monomoy Beach. Reduction of this flow has made possible Nauset Beach to be growing nearer to Monomoy Beach, thus constricting that opening and causing further diversion of flow through the breach.

55. If a dike is constructed across the breach, the fact should be recognized that the present proximity of Nauset Beach to Monomoy Beach will tend to be altered by the increased flow through that opening. It is expected that, in this process, and until the opening has become sufficiently large, considerable erosion will be experienced by both the dike and Nauset Beach. It would, therefore, appear essential for the dike to be designed so that it could survive the adjustment period.

56. An important factor in connection with construction of a dike across the breach, as well as any dredging project, is the expectation that further changes from the present conditions will occur in the interim period up to the time of the actual construction. These changes can affect the construction limits and volumes, and possibly warrant certain design modifications to fit more effectively to the then conditions. These changes are difficult to evaluate and to place on a time schedule. However, study has been made of past trends and certain assumptions of probable changes included, in order to guide the determination of the necessary allowances.

57. In the analysis of the behavior of the breach area, a set of comparative profiles was prepared, as shown on Plate 3. The location of these profiles is shown on Plate 5. Profiles J to S are generally across

the channel around the bend off the tip of Harding Beach. Profiles T to Y are located across the breach. Profiles 7 and 8 extend along the breach and are repeat profiles of those reported in the beach erosion report of 1956.

58. The above profiles reflect the continuing shoaling of the channel area and enlargement and shifting of the natural breach channel. This trend is expected to continue at nearly similar rates in the immediate future. This process will then slowly decelerate and continue at lower and relative stable rates.

59. An analysis has also been made of the past shoaling history of the present federal channel. Ten different surveys since 1950 were used in the study. The presently authorized federal channel, as constructed in 1957, was divided into 71 shoaling analysis subareas, as shown on Plate 4. Each of these subareas was, in turn, divided into generally 50-foot wide strips to cover separately the center of the channel, the left and right parts of the channel, the left and right side slope area and the left and right outside areas, all as shown on Plate 4.

60. From each survey the average depth in each strip was determined and tabulated. The difference of these depths was then obtained for each survey interval available. This change in depth was then converted into annual rates for the corresponding survey intervals. Most strips and rates between survey intervals show shoaling. However, there are some cases where limited scour, or negative shoaling, were evident for certain strips in certain survey intervals, exclusive of the intervals which involved dredging operations.

61. The above rates were analysed for each channel subarea and mean rates were developed to reflect the conditions prior and after the breach; the surveys of 1957 taken as the time of change. Negative rates were separated and not included in the mean rates of shoaling. These mean rates for each channel subarea are shown on Plate 4. Negative values should not be subtracted from the shoaling rates in attempting to establish net shoaling rates, since the negative rates generally cover a smaller proportion of the channel area and the survey intervals. The above analysis has been useful in determining annual channel maintenance rates for the various plans considered with and without closure of the breach.

62. Study of the shoaling rates of the approach channel and the first bend near Harding Beach indicates that these are not excessive. Therefore, it is considered that a jetty or groin at this location, to prevent whatever eastward littoral drift exists, is not warranted, nor would it be economically justified.

63. Study of the changing shoaling rates in the vicinity off the tip of Harding Beach indicates that it would be impractical, if not impossible, to maintain a channel at this location, while the breach remains open, at least in the immediate and near future. It would appear, therefore, that a dike across the breach is a necessary component for any plan contemplating to maintain a channel at, or near, the location of the presently constructed channel.

64. Relocation of the channel across Harding Beach would not wholly escape the effects of the breach, if it is permitted to remain open. The comparative shoaling rates of the approach and harbor channels have shown a definite increase after the breach. The shoaling rates, particularly of the approach channel, are expected to show increases in the near future as the shoal front approaches that area.

65. Study has also been made of shoreline changes in the area. These are analysed and presented in detail in the beach erosion reports of 1941 and 1956. The past trends have been generally continued up to the present time. It is considered appropriate to add here that it is expected that Harding Beach, whose tip has eroded as a result of the breach, will again grow to its previous position after closure of the breach. This should, therefore, be accounted for in any modification of the present channel layout.

66. Whether the present breach is closed, or not, it is possible that other breaches may occur at other vulnerable areas of Monomoy Beach and Island. Such future breaches are, generally, expected to have little impact upon the project area, if located a sufficient distance to the south. Determination of the minimum no-effect radius is difficult. Estimates, however, indicate that the effects would be progressively smaller with distance, and that the significance of such effects on the channel would be sufficiently small if a future breach is located more than one mile to the south of Morris Island.

67. Quantities and Costs. - In determining quantities of dredging and fill for the dike the surveys of 1962, supplemented by the survey of 1961, were used. These would represent the approximate quantities to be encountered if construction is undertaken at present, i.e., in the summer of 1962. Quantities of dredging or fill to be required in 1963 are expected to be generally higher than the present volumes. Estimates of this increase have been made and are indicated where applied.

68. All plans which include construction of a dike to close the breach will have about the same first cost of construction, since the quantities required for the dike are in excess of any contemplated channel dredging.

69. The sand fence system on the dike would be more elaborate for the plans which call for a channel around Harding Beach. Seeding of beach grass has been allowed for both the dike and the banks of a relocated channel. Sand fences are provided on Harding Beach for the relocated channel plans and on the dike.

70. Interest and amortization charges have been based on an interest rate of 2.625% for 50 years. Contingencies have been based on 12% of the construction cost. Unit costs are based on prevailing 1962 prices. The cost of this study is not included in these estimates.

71. Maintenance requirements are based on average annual rates expected to prevail during a 50-year period, which is taken as the economic life of the project. The maintenance requirements of individual years can vary considerably from the above average rates.

72. The estimated quantities, costs and annual charges for the plans considered are presented below:

a. PLAN A. - Maintain the present channel as constructed in 1957, without closing the breach.

First Cost of Construction	1962	1963
Dredging volume (c.y.)	260,000	310,000
Unit Price ($/c.y.)	0.90	
Dredging cost	$234,000	$279,000
Contingencies	28,000	33,000
Engineering and Design	12,000	
Supervision and Administration	26,000	
Total First Cost	$300,000	$350,000
Annual Charges		
Interest	$ 7,900	$ 9,200
Amortization	3,000	3,500
Maintenance dredging	50,000	
Total Annual Charges	$60,900	$62,700

b. PLAN C. - Maintain the existing channel and construct a dike to close the breach. The first cost and annual charges of this plan are essentially the same as Plan C-modified, except that there is a difference in the volumes of channel dredging. The volumes for channel dredging for Plan C are same as Plan A. Plan C-modified requires additional about 100,000 c.y., but, since the dike volume is larger, the costs are the same for the two plans.

c. PLAN C-modified. - Construct a channel around Harding Beach, modifying the present alignment, so as to eliminate certain bends and widen those remaining. In addition, construct a dike to close the breach, 5000 feet long, or more.

First Cost of Construction	1962	1963
Volume for dike (c.y.)	450,000	560,000
Cost of dike @ 0.80 $/c.y.	$360,000	$448,000
Grass seeding @ 0.05 $/s.f.	70,000	
Sand fences @ 2 $/ft.	10,000	
Contingencies	53,000	63,000
Engineering and Design	14,000	
Supervision and Administration	43,000	45,000
Total First Cost	$550,000	$650,000
Annual Charges		
Interest	$ 14,500	$ 17,100
Amortization	5,500	6,400
Maintenance	12,500	
Total Annual Charges	$ 32,500	$ 36,000

d. PLAN D. - Relocate the channel across Harding Beach using a cut section with 1 on 12.5 side slopes and 150-foot base. Leave the breach open, but use the material from the dredging to form mounds on either side of the breach, in order to confine it and to prevent its expansion. The quantity of dredging may be expected to increase some by 1963 from 1962. However, this increase may be considered relatively small for estimating purposes, and, therefore, one estimate has been prepared.

First Cost of Construction	
Dredging volume (c.y.)	400,000
Dredging cost @ 0.85 $/c.y.	$340,000
Grass seeding @ 0.05 $/s.f.	10,000
Sand fences @ 2 $/ft.	5,000
Contingencies	43,000
Engineering and Design	13,000
Supervision and Administration	39,000
Total First Cost	$450,000

Annual Charges

Interest	$11,800
Amortization	4,500
Maintenance	10,700
Total Annual Charges	$27,000

e. PLAN D - modified. - Same as Plan D, except that it includes a dike closing the breach. First costs are essentially the same as Plan C-modified, presented in detail above. The total first cost is estimated at $550,000 for 1962 and $650,000 for 1963. Interest and amortization amount to $20,000 and $23,500 for the above, respectively. The annual cost of maintenance has been estimated at about $6,500. The total annual charges, therefore, amount to $26,500 and $30,000 for construction of the project in 1962 and 1963, respectively.

f. PLAN E. - Same channel relocation as Plan D. In addition, it includes a dike across the mouth of Stage Harbor. The first cost would be same as Plan D, or $450,000. Somewhat greater maintenance requirements would make the total annual charges to amount to about $28,000.

g. PLAN G. - Relocate the approach channel across the flats to eliminate the bend near Harding Beach and re-align the channel inside the harbor as in Plan C-modified. Construct dike to close the breach. The first cost and annual charges will be similar to those presented under Plan C-modified. However, the entire volume required for the dike will have to be obtained from dredging of the channel, thus eliminating the opportunity to obtain the extra quantities by dredging anchorage areas inside the lower harbor.

h. PLAN H. - Similar to Plan C-modified, except that portion of the dike will be constructed with stone fingers adjacent to the natural breach channel, thus leaving a confined opening. This plan is estimated to require a first cost of upwards of $700,000 and to have annual charges of the order of $50,000.

73. Discussion. - The various natural factors and processes and the relative effects upon the project area have been discussed above. In addition, various statements have been made as to the effect and effectiveness of various design components. Additional

discussion of the relative effectiveness of the plans considered, partly summarizing earlier comments, is given below.

74. The most practical solution to the present problems is considered to be complete closure of the breach, as provided by any of the Plans C, C-modified, D-modified and G. Plans C, C-modified and D-modified require less channel dredging than required for the dike construction, thus making possible some additional dredging in the lower harbor, outside the channel limits. This extra dredging would provide additional area of anchorage with some benefit to the project. This is a disadvantage of Plan G.

75. Plan G may also distrub and/or destroy any shellfish beds across the flats. It has the advantage of being a straighter channel than either Plan C or C-modified, but follows a new route, to which local boatmen are not accustomed.

76. Plan C-modified has similar advantages, disadvantages and other effects as Plan C. It is generally along the old route, to which local boatmen are accustomed, and has the added advantage of being straighter than Plan C.

77. All plans with a channel around Harding Beach have the advantage of leaving Harding Beach undisturbed and maintaining the present protection afforded to Stage Harbor. Any of Plans D, D-modified or E, which have a channel relocated across Harding Beach, will make the harbor vulnerable, to a small degree, from waves in Nantucket Sound. This would result in some increase of the chop condition in Stage Harbor.

78. Plans D, D-modified and E have the distinct advantage of providing the shortest, straightest, and most economical channel into Stage Harbor.

79. Plan E has the disadvantages of leaving the breach open and of greater currents in the channel. Plan D also has the disadvantage of leaving the breach open. Some of the objections to any plan leaving the breach open are that frequent maintenance of the project will be necessary, and a condition is allowed to exist which is unstable, continually changing and shifting, and encroaching upon the project. In addition, it is detrimental to shellfish beds, as sediment is deposited and the temperature of the water lowered by inflow of water from the ocean. Some of these objections would apply even if the breach opening is controlled, as in Plan H.

80. The main advantage of leaving the breach open, or permitting a controlled and confined opening, is that it permits navigation from the Nantucket Sound to the Pleasant Bay area. However, this advantage is offset by the reported shoaling of the ocean channel, off Nauset Beach, due to diversion of some of the flow through the breach.

81. Navigation would probably be easier under Plans D, D-modified, and E, particularly for the visiting transient fleet. A note on the U.S.C. & G.S. Chart to the effect that the present channel is difficult to navigate might be removed, if any of the above plans were constructed. The above plans will have the added benefit to the U.S. Coast Guard in the form of reduced maintenance costs for navigation aids. Plan D-modified, in particular, has been officially favored by the Coast Guard.

82. Stage Harbor is reported to be experiencing some winter ice jamming at present, and certain local interests fear worsening of these conditions under any of Plans D, D-modified and E. Although Plan E may affect this condition adversely, it does not appear likely that either Plan D or D-modified will contribute to any worsening of the presently existing conditions.

83. Plans D and D-modified have a disadvantage in that they create an island of a portion of Harding Beach, thus making it inaccessible by land.

84. The threat of future breaches across Monomoy Beach, and even the possibility of failure of the proposed dike, present certain advantages for relocation of the channel across Harding Beach, so as to be located farther away from the danger area. However, a channel relocated across Harding Beach has the disadvantage of being bounded by land and, therefore, more susceptible to shoaling by deflation.

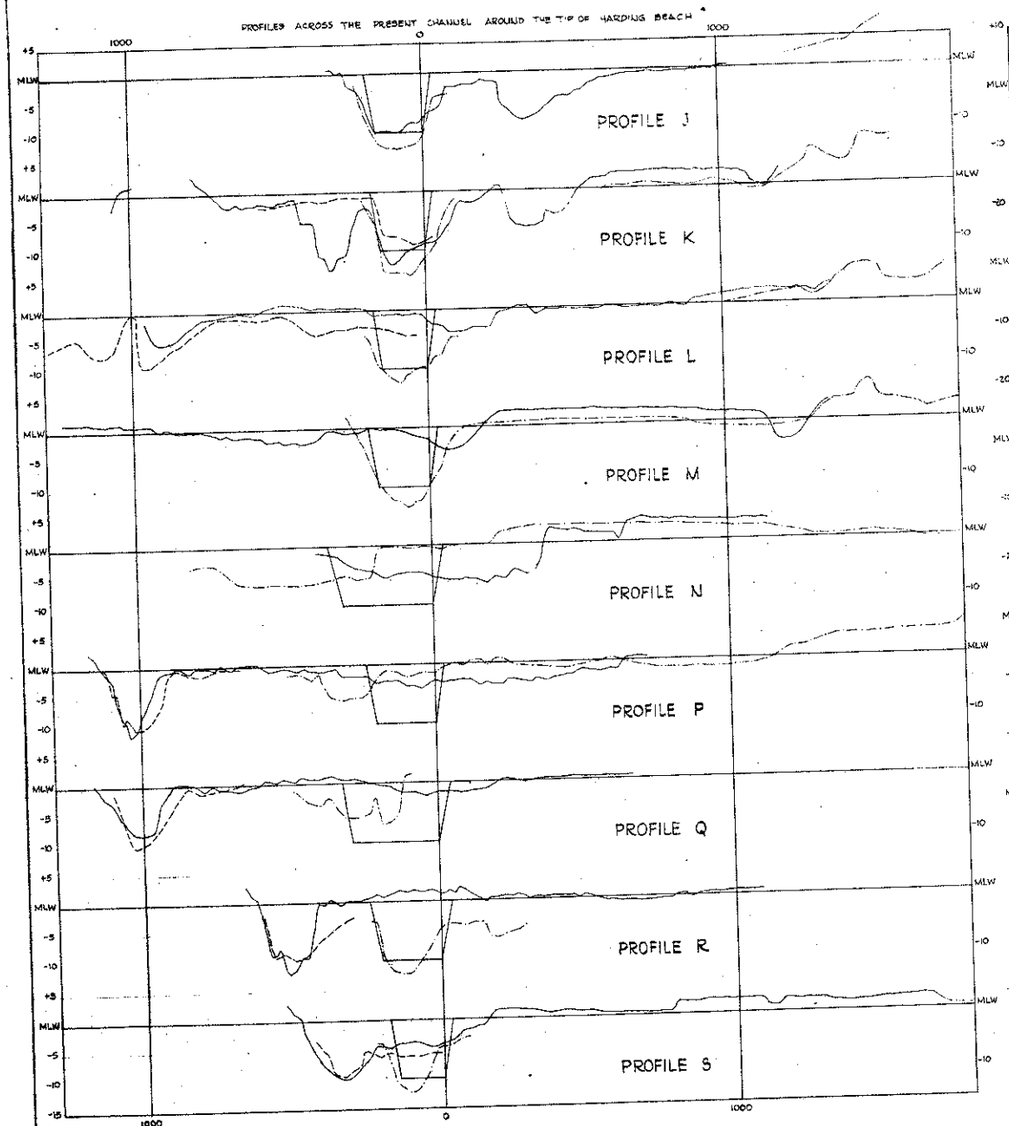
85. Plan C-modified was overwhelmingly favored by local interests at a recent public hearing held by the Town to determine local attitudes.

86. Conclusion. - After careful study and analysis of the factors affecting the project, the relative effectiveness and cost of each plan considered, it is concluded that although Plan D-modified is the least expensive solution to the problem. Plan C-modified is the most desirable and practical project.

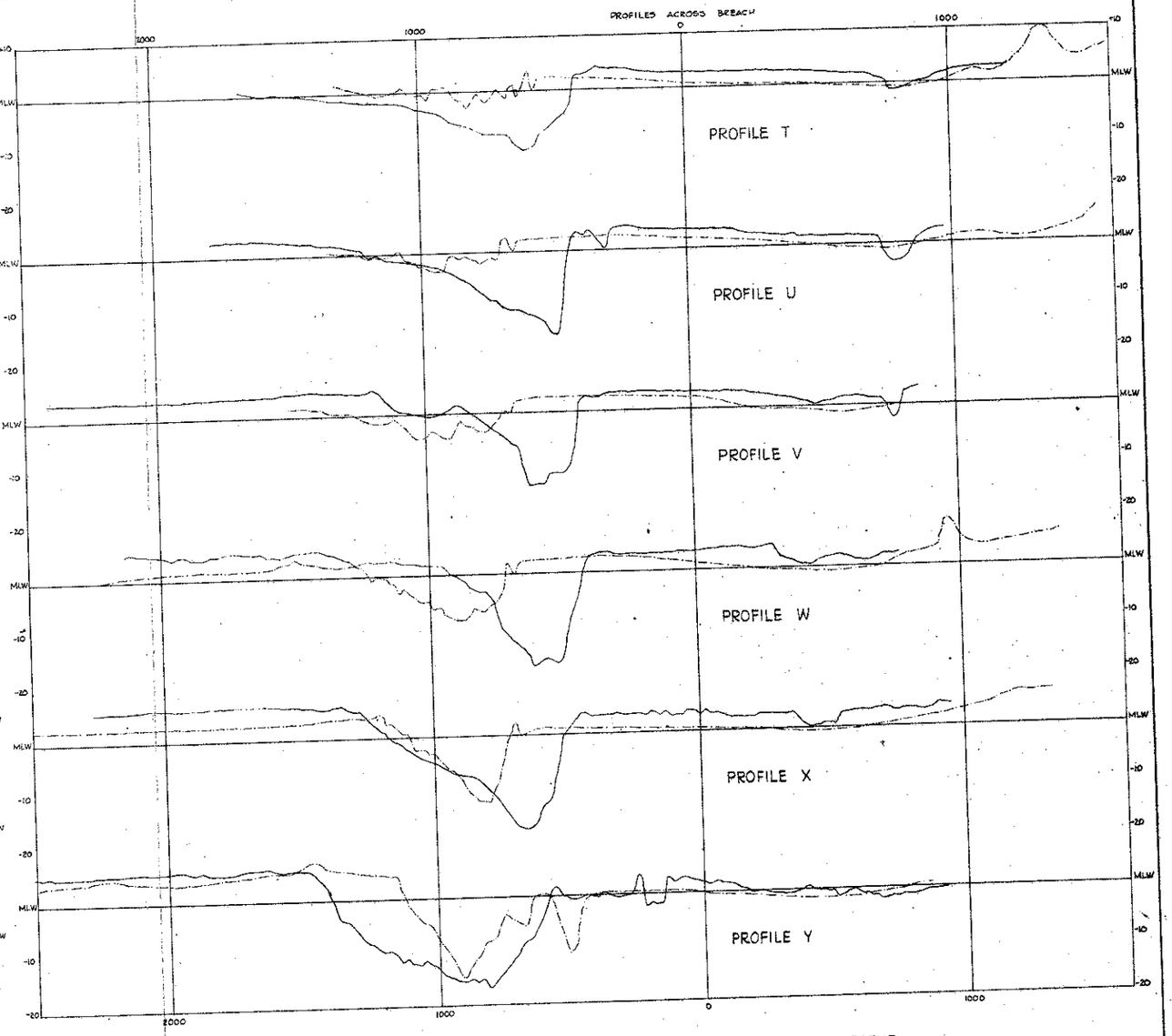
CORPS OF ENGINEERS

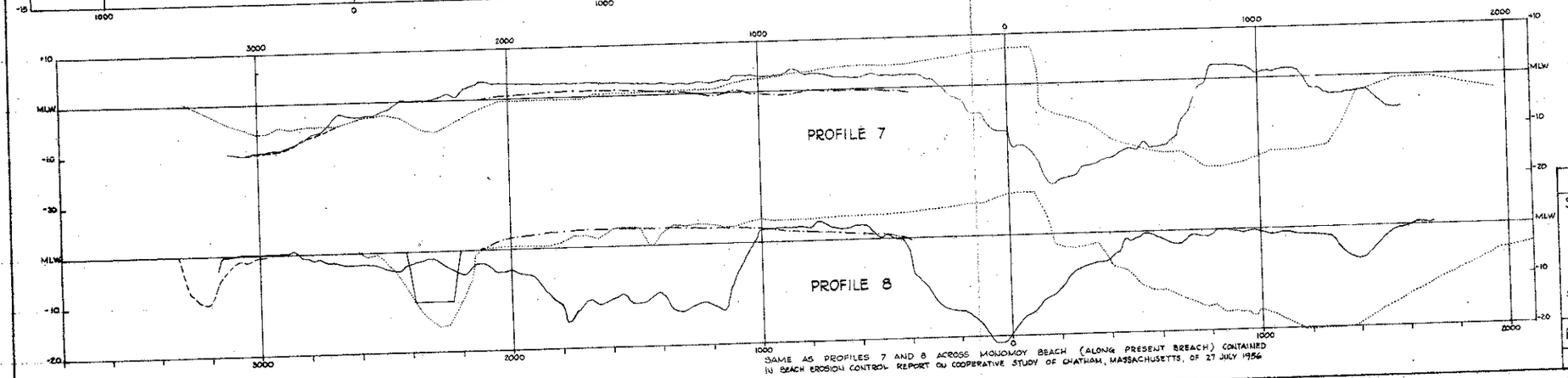
U. S. ARMY

PROFILES ACROSS THE PRESENT CHANNEL AROUND THE TIP OF HARDING BEACH



PROFILES ACROSS BREACH





SAME AS PROFILES 7 AND 8 ACROSS MONOMOY BEACH (ALONG PRESENT BREACH) CONTAINED IN BEACH EROSION CONTROL REPORT ON COOPERATIVE STUDY OF CHATHAM, MASSACHUSETTS, OF 27 JULY 1956

LEGEND
- MAY 1962
- FEBRUARY 1962
- AUGUST 1961
- MARCH 1955

U.S. ARMY ENGINEER DIVISION, NEW ENGLAND
CORPS OF ENGINEERS, WALTHAM, MASS.

STUDY OF CHATHAM (STAGE) HARBOR CHANNEL
CHATHAM, MASS.

PROFILES

SCALES: VERTICAL 0 10 20 30 40 50 FEET; 0 200 400 600 800 1000 HORIZONTAL

REPORT ON ALTERNATIVES CONSIDERED — JULY 18 1962

A. A. VULGAROPULOS ◦ CONSULTING ENGINEER ◦ WALTHAM

FILE NO. Cm 25 SHEET 1 OF 3

PLATE 3

CORPS OF ENGINEERS

U. S. ARMY

NANTUCKET SOUND

CHATHAM ROADS

HARDING BEACH

STAGE HARBOR

MORRIS ISLAND

HARDING WEST (1938)

HARDING EAST (1938)

BLUFF (1938)

N 243,000 E 1,012,000

N 246,000 E 1,019,000

N 245,000 E 1,018,000

N 244,000 E 1,019,000

N 243,000 E 1,018,000

N 242,000 E 1,019,000

N 241,000 E 1,018,000

N 240,000 E 1,017,000

N 239,000 E 1,016,000

N 238,000 E 1,015,000

N 242,000 E 1,013,000

N 241,000 E 1,012,000

N 240,000 E 1,011,000

SURVEYS USED IN THE ANALYSIS

APRIL 27 - MAY 2, 1950	EXAMINATION	
MARCH 14-18, 1955	"	
FEBRUARY 24-29, 1956	"	
JUNE 12, 1956	AFTER DREDGING	
JULY 24, 1956	"	
JANUARY 31 - FEBRUARY 14, 1957	SPEC. SURVEY	
SEPTEMBER 25-OCTOBER 11, 1957	AFTER DREDGING	
JULY 18-27, 1961	CONDITION SURVEY	
FEBRUARY 1962	"	(TOWN OF CHATHAM)
MAY 4-18, 1962	"	

NOTES

CHANNEL SUBAREAS ARE NUMBERED IN THE DIRECTION OF THE HARBOR.

EACH SUBAREA GENERALLY COVERS 800 FEET ALONG THE CHANNEL, EXCEPT AT BENDS.

EACH SUBAREA IS DIVIDED INTO STRIPS ALONG THE CHANNEL. STRIPS ARE 50 FEET WIDE, EXCEPT AT CERTAIN BENDS.

EACH STRIP IS DESIGNATED AS FOLLOWS:

- O/L = OUTSIDE LEFT
- S/L = SLOPE LEFT (ADJACENT TO CHANNEL)
- L = LEFT 50 FEET OF CHANNEL
- CENTER = CENTER OF CHANNEL
- R = RIGHT 50 FEET OF CHANNEL
- S/R = SLOPE RIGHT (ADJACENT TO CHANNEL)
- O/R = OUTSIDE RIGHT

ANNUAL RATES OF DEPOSITION OR SCOUR (IN FEET) IN THE CHANNEL, BEFORE AND AFTER THE BREACH, ARE SHOWN OUTSIDE THEIR RESPECTIVE CHANNEL SUBAREAS. SCOUR IS INDICATED BY THE NEGATIVE SIGN (-). THE BEFORE AND AFTER RATES ARE SHOWN AS FOLLOWS: BEFORE/AFTER

WHERE SIGNIFICANT CHANGES IN THE AFTER THE BREACH RATES EXISTED BETWEEN SURVEYS, THESE ARE SHOWN ON SEPARATE LINES AS FOLLOWS: BEFORE
AFTER (1957-1961)
AFTER (1961-1962)
AFTER (1962-1962)

ESTIMATED RATES BASED ON SPARSE INFORMATION ARE SHOWN IN PARENTHESES.

U. S. ARMY ENGINEER DIVISION, NEW ENGLAND
CORPS OF ENGINEERS, WALTHAM, MASS.

STUDY OF CHATHAM (STAGE) HARBOR CHANNEL
CHATHAM, MASS.

CHANNEL SHOALING ANALYSIS
SUB-AREAS

SCALE 0 200 400 600 800 1000 FEET

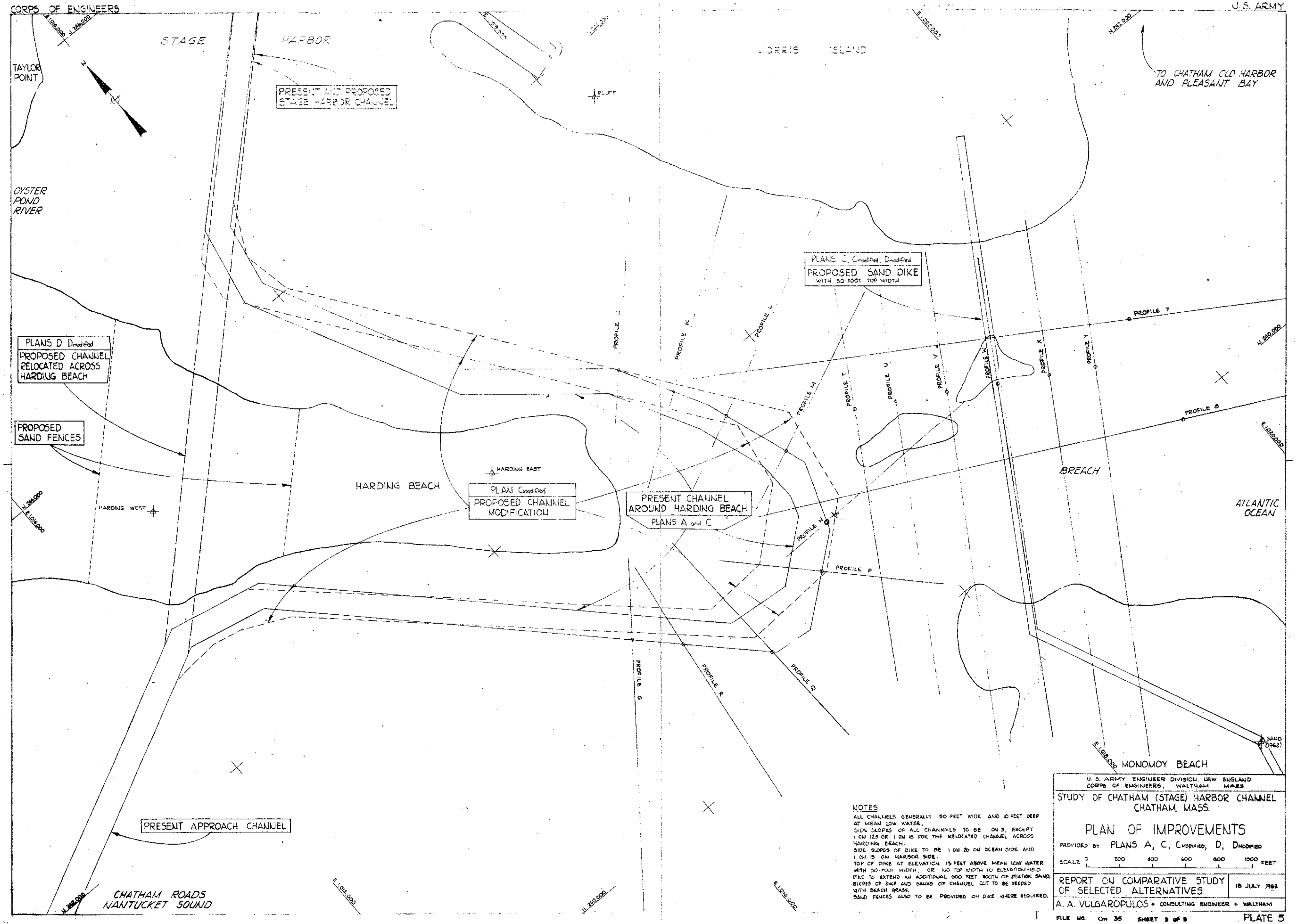
REPORT ON COMPARATIVE STUDY OF SELECTED ALTERNATIVES

18 JULY 1962

A. A. VULGAROPULOS • CONSULTING ENGINEER • WALTHAM, MASS.

FILE NO. Cm 55 SHEET 2 OF 3

PLATE 4



NOTES

ALL CHANNELS GENERALLY 150 FEET WIDE AND 10 FEET DEEP AT MEAN LOW WATER.
SIDE SLOPES OF ALL CHANNELS TO BE 1 ON 3, EXCEPT 1 ON 12.5 OR 1 ON 18 FOR THE RELOCATED CHANNEL ACROSS HARDING BEACH.
SIDE SLOPES OF DIKE TO BE 1 ON 20 ON OCEAN SIDE AND 1 ON 15 ON HARBOR SIDE.
TOP OF DIKE AT ELEVATION 15 FEET ABOVE MEAN LOW WATER WITH 50-FOOT WIDTH, OR NO TOP WIDTH TO ELEVATION +15.0
DIKE TO EXTEND AN ADDITIONAL 500 FEET SOUTH OF STATION SAND.
SLOPES OF DIKE AND BANKS OF CHANNEL CUT TO BE SEEDED WITH BEACH GRASS.
SAND FENCES ALSO TO BE PROVIDED ON DIKE WHERE REQUIRED.

U. S. ARMY ENGINEER DIVISION, NEW ENGLAND
CORPS OF ENGINEERS, WALTHAM, MASS.

STUDY OF CHATHAM (STAGE) HARBOR CHANNEL
CHATHAM, MASS.

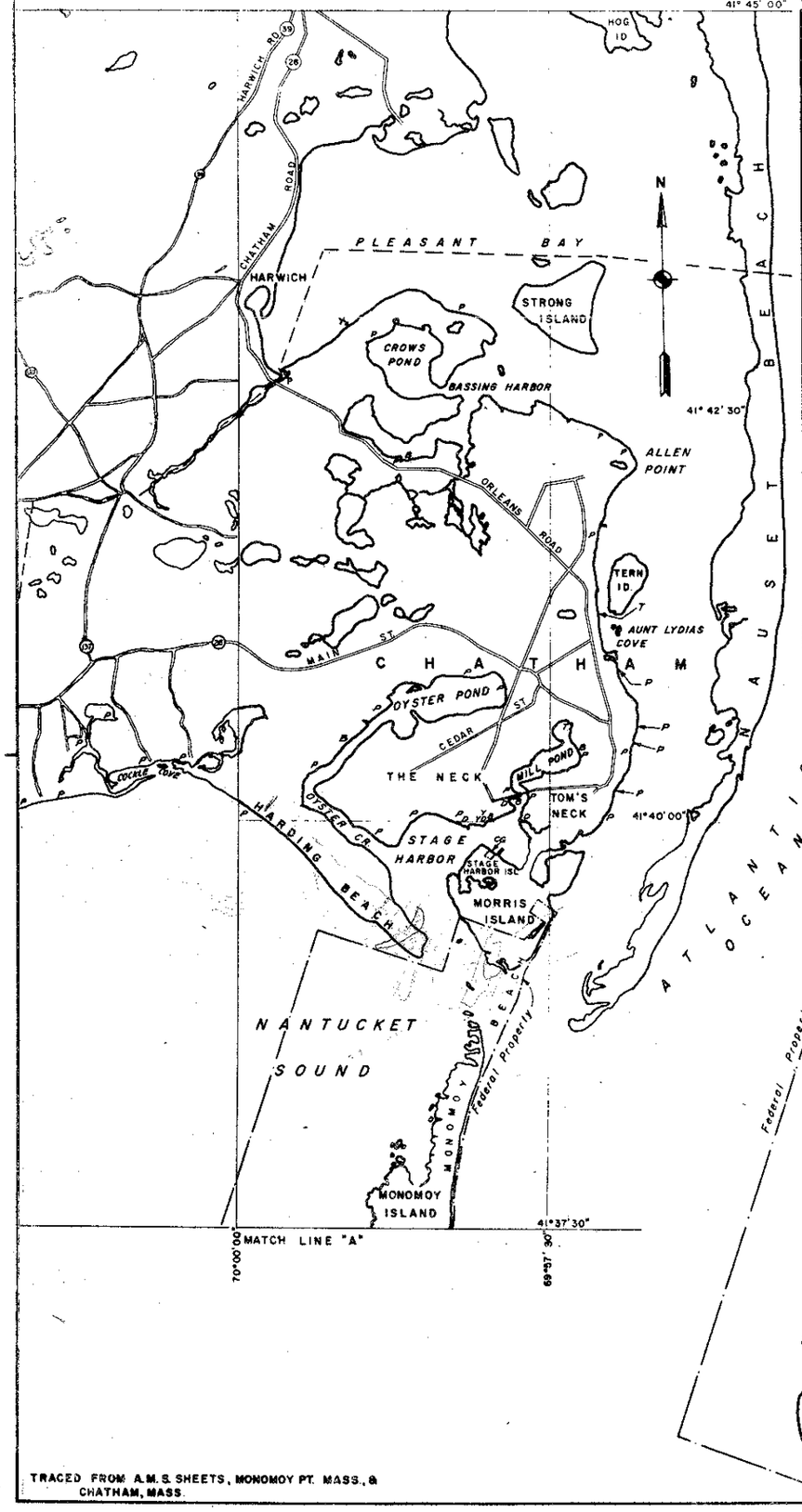
PLAN OF IMPROVEMENTS

PROVIDED BY PLANS A, C, Cmodified, D, Dmodified

SCALE 0 200 400 600 800 1000 FEET

REPORT ON COMPARATIVE STUDY OF SELECTED ALTERNATIVES | 18 JULY 1962

A. A. VULGAROPULOS • CONSULTING ENGINEER • WALTHAM



TRACED FROM A.M.S. SHEETS, MONOMOY PT. MASS., & CHATHAM, MASS.

NOTES

1. WIND ROSES

Basic wind data was available in part based on 8-points of the compass and the remainder based on 16-points of the compass. In order to present comparative diagrams, wind duration and movement for Nantucket are shown in percent per degree of direction. To obtain percentage of duration or movement for 8-point increment of direction multiply given pecentage by 45, for 16-point increment multiply by 22.5.

Nantucket data from U.S. Weather Bureau records. Chatham data from U.S. Coast Guard records and compiled by Massachusetts Dept. of Public Works.

2. WAVE ROSE

Traced from enlargement of figure B-1, Beach Erosion Board Technical Memorandum Number 55.

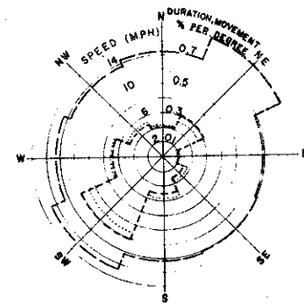
3. MAPS

Shore lines are referred to mean sea level (1929 datum).

Federal owned property consists of Fish and Wild Life Refuge on Monomoy Island under the jurisdiction of Fish and Wildlife Service, Department of the Interior, and limits are indicated by (— — —). U.S. Coast Guard property designated by C.G.

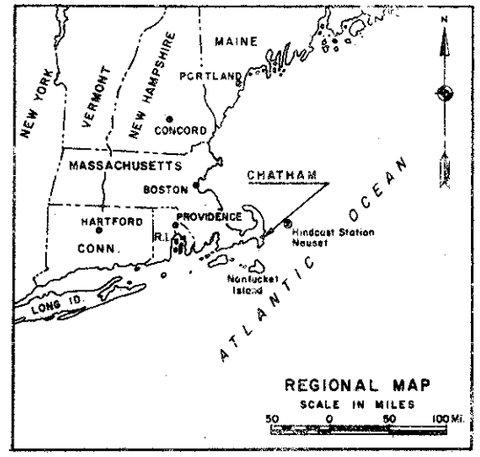
Nauset Beach will be included in the proposed Cape Cod National Seashore Park.

The town of Chatham owns Harding Beach and portions of Nauset Beach.

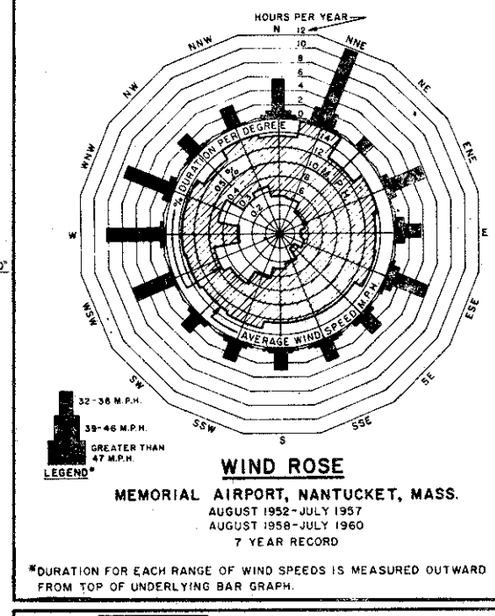


WIND ROSE
NANTUCKET, MASS.
1918 - 1937

LEGEND
DURATION IN PERCENT PER DEGREE.
MOVEMENT IN PERCENT PER DEGREE.
AVERAGE SPEED IN M.P.H.

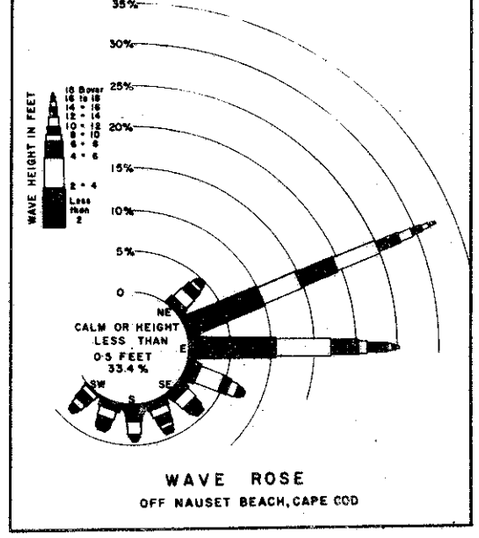


REGIONAL MAP
SCALE IN MILES
50 0 50 100 Mi.

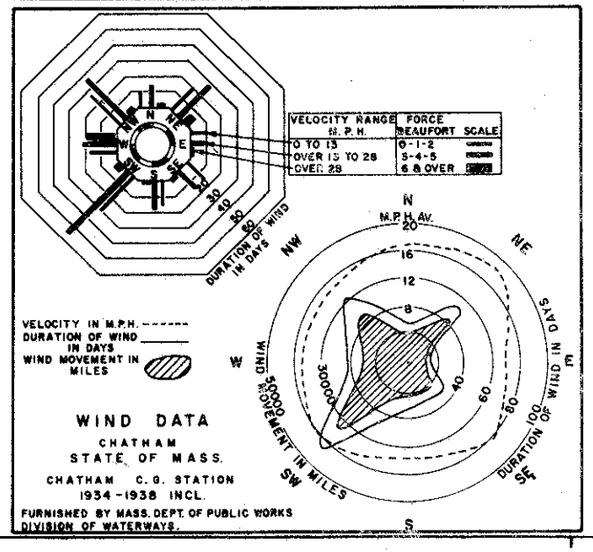


WIND ROSE
MEMORIAL AIRPORT, NANTUCKET, MASS.
AUGUST 1952-JULY 1957
AUGUST 1958-JULY 1960
7 YEAR RECORD

*DURATION FOR EACH RANGE OF WIND SPEEDS IS MEASURED OUTWARD FROM TOP OF UNDERLYING BAR GRAPH.



WAVE ROSE
OFF NAUSET BEACH, CAPE COD



WIND DATA
CHATHAM
STATE OF MASS.
CHATHAM C.G. STATION
1934-1938 INCL.
FURNISHED BY MASS. DEPT. OF PUBLIC WORKS DIVISION OF WATERWAYS.

LEGEND

C G	Coast Guard
T	Town landing or dock
P	Public shore access
D	Commercial dock
B	Boat yard
Y	Yacht club

U.S. ARMY ENGINEER DIVISION, NEW ENGLAND
CORPS OF ENGINEERS, WALTHAM, MASS.

CHATHAM (STAGE) HARBOR, MASS.
WIND AND WAVE DATA
SCALE IN FEET
2000 0 2000 4000 6000 8000

REPORT ON COMPARATIVE STUDY OF SELECTED ALTERNATIVES

18 July 1962

A. A. VULGAROPULOS
CONSULTING ENGINEER · WALTHAM, MASS.

FILE NO. Cm 36

PLATE 6